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Metals and Alloys

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In so many kinds

DESIGNERS, NOTE!

Broadly speaking, U·S·S COR-TEN can be applied to effect operating economies, to increase strength or to prolong life in practically every kind of equipment that must be moved, or that must lift, support, or move other materials. U·S·S COR-TEN has been used successfully for—

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Blowers
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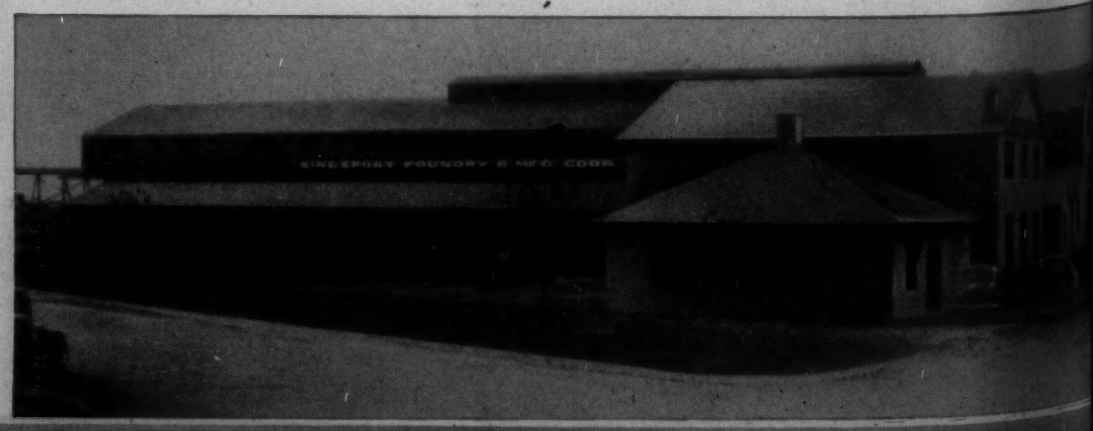
U·S·S COR-TEN is available in all standard forms—plates, shapes, bars, sheet, strip, special cold formed sections and other products. *To get best results with* COR-TEN *it will be helpful to note with your inquiry or order, the purpose and the fabrication procedure contemplated.*

COR-TEN BUILDS WORLD'S LARGEST LOGGING TRUCK UNIT. To give the maximum strength and stamina with minimum weight, this mammoth motor haul unit, built by the Kenworth Motor Truck Corporation, uses COR-TEN construction throughout. Designed to carry a payload of 110,000 lbs., these units will carry 15,000 ft. of logs per trip at average speeds of 25 miles per hour with full load—a total of about 75,000 ft. of Ponderosa pine per day on a haul of 15 miles. Used by the Lakeview Logging Co., Lakeview, Oregon, this truck is hauling 22,140 ft., believed to be largest load of logs ever carried by a truck and trailer.

MARINE APPLICATIONS—U·S·S COR-TEN USED IN FLOOD WATER CONTROL. This Tainter Gate, fabricated by R. C. Mahon Company, Detroit, Michigan, is one of fifteen used in a river dam for flood control. These gates are of a special type and are longer than any previously constructed, the length of the drum being 75′ 2½″ face-to-face of end shield plate. Total weight of each Tainter Gate including all movable parts is 232,430 lbs., which 212,000 lbs. is COR-TEN Steel.

COR-TEN ROOF RESISTS SEVERE CORROSIVE CONDITIONS. *(Below)* Applied to the roof of this foundry building where ordinary light gage roofing sheets were rapidly destroyed, COR-TEN has given excellent service. The U·S·S COR-TEN corrugated sheets—hot rolled, annealed, 22-gage—were applied in December 1935, and painted with red oxide of iron paint. When examined almost 3 years later no deterioration was detected except adjacent to the smoke stacks, and even here was very slight.



UNITED STATES STEEL

Feature Section

Air-Conditioned Autos

Herbert Chase has contributed another of his interesting general articles—this time on the metals and alloys that are used in successfully operating an air-conditioned automobile. Those used are many.

Hydrogen in Steel

In this issue we bring to a close an important correlated abstract on hydrogen as related to flakes, shattercracks and allied defects in steel. The three preceding installments appeared in our May, June and July issues. They all throw important light on a problem which has been before metallurgical engineers for many years.

Pearlitic Malleable

Your editor, as a result of a visit at the fine plant of the Belle City Malleable Iron Co., Racine, Wis., was impressed by the method this company uses in producing pearlitic malleable iron—the only company using an electric arc furnace for this purpose. To us it is an interesting recital.

Powdered Copper

Dr. Goetzel concludes in this issue his discussion on powdered copper. We feel that articles now and then on phases of powder metallurgy are necessary and appropriate in a field rapidly gaining in importance. The first installment appeared in July.

Copper in Cast Iron

Another discussion, commenced in the July issue, is concluded in this—effect of copper as an alloy in certain cast irons made in an electric furnace by Barlow. He states that copper either alone or with certain other elements, is useful as an alloy addition and that definite benefits result.

Flame Hardening Metallurgically

Flame hardening has come to the front rapidly in recent years. Its success is due not only to the equipment but also to certain metallurgical considerations. Much has been published on the process and the equipment. Here we offer an authoritative discussion of the metallurgical phases by Mr. Day.

Engineering Digests

Steel Castings

The steel casting industry is not standing idly by while gray iron castings, malleable castings, forging and rolled steel construction—all of which are its competitors—are steadily improved. A composite on page 184 surveys improvements in the manufacture of steel castings that have elevated the quality standards of this metal-form.

Lead Smelting

How do you want your air controlled in operating a lead smelter—by volume or by pressure? Miller, Bainbridge and Ellison (page 190) plunge into the debate with strong support for pressure control.

Paints

A composite on page 192 collects recently-published information on painting and paints for steel. The popularity of phosphate pre-treatments is affirmed, and some interesting dope about inhibitive priming paints is given.

Designing for Die Castings

A composite that starts with the assumption that die castings have been selected as the best metal-form for a given part and proceeds to show how to design the part to get the best value from the die casting is presented on page 214.

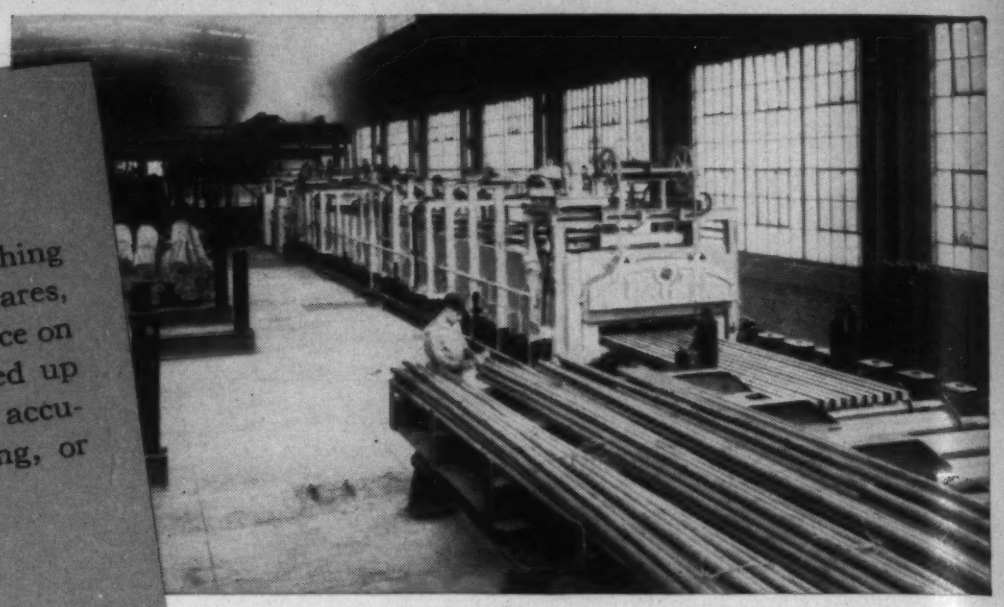
Rails

Controlled-cooled rails, end-hardening methods and results, shatter-crack tests, and continuous welded rails are all discussed in a composite digest of this year's progress reports on rail investigations at the University of Illinois.

Electrical Heating Alloys

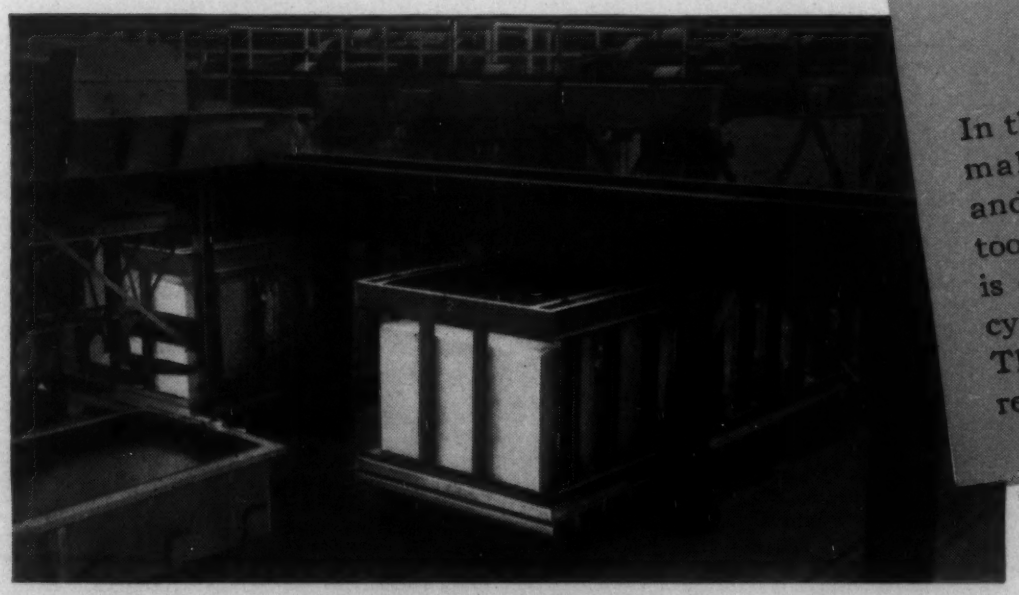
Some other-than-political contrasts between America and Europe are presented by a composite of recent articles on the life testing of electric resistors. Different philosophies of use and testing are clearly evident, at least with respect to German and American practice.

30-ft BAR STOCK—Every Inch Heat-treated Accurately and Uniformly IN G-E ELECTRIC FURNACES



ROLLER-HEARTH TYPE

Used where large capacity for quenching or normalizing is desired. Rounds, squares, or flats are carried through the furnace on driven rolls. The hot bars are picked up quickly by an automatic crane and accurately quenched with electric timing, or they can be cooled in air.



BELL TYPE FOR FLEXIBILITY

In these G-E car furnaces, quenching, normalizing, spheroidizing, drawing, and annealing can be done. Here, too, the crane is automatic, and quenching is controlled by electric timers—previous cycles can be duplicated time after time. This assures complete satisfaction in filling repeat orders.

MORAL FOR HEAT TREATERS

You may not heat-treat bar stock, but probably do heat-treat parts that demand the same degree of precision and uniformity. General Electric can supply electric equipment that will do it accurately and economically—equipment that is backed by years of experience and the engineering skill embodied in the giant electric furnaces pictured above. General Electric Co., Schenectady, New York.

GENERAL ELECTRIC

675-12

Tailor-made

It is often said that this is the era of tailor-made steels, steels adjusted by grain size control, alloying and heat treatment, to specific and exacting uses. Every special steel producer works with his customers to give them just what they want. The users attack their own problems and often find that one solution lies in a new steel or a special mill processing of a standard steel. Producers of ferroalloys, deoxidizers, etc., are alert to publicize cases of useful application of their products. The amount that gets published about specialities, because of their glamor and news value and the relative attention paid to specialities by technical societies, is all out of proportion to their economic importance.

A hunchback has to have a tailor-made suit, but only a small proportion of the population is hunchbacked. He probably averages more intelligent than normally proportioned people so that it is quite necessary that he be clothed and brought into contact with the rest of humanity. But that doesn't mean that making clothes for him is a large industry, nor does anyone expect that such clothes can be ordered from Sears or Montgomery Ward or at bargain prices.

The student who would readily sense the situation in respect to clothes is likely to have quite a false perspective in respect to steel, just because he has heard and read so much about special steels. A good antidote is available for students, one that might also be taken by those metallurgists and purchasing agents of users who have not had enough contact with production to grasp the economics or cost of special compositions, special processing, special dimensional limitations and of handling small orders. This antidote is a series of papers presented at the American Iron and Steel Institute meeting, by Earle Smith on meeting chemical specifications, by Charles Herty on meeting mechanical specifications, and by A. C. Cummins on meeting dimensional tolerances.

These papers should be required reading for professors, students and research men. They bring out clearly how low the yield may be of material that has to meet a specially difficult, or even an unusual, though not necessarily an inherently difficult, requirement.

It was certainly not the object of the authors of these papers to minimize the value of special products for special uses, but rather to lay a better foundation for cooperation between producer and user so that the latter may be more prone to lay all the cards on the table and consult with the producer rather than merely ask for a take it or leave it quotation on a stringent specification which on engineering examination may not prove to be necessary in all its requirements.—H. W. G.

The "Significant Steels"

The movement to make up a list of "Significant Steels," set in motion by the papers of Earle Smith and C. H. Herty, Jr., at the Iron and Steel Institute meeting, which pointed out the cost of making up small orders of special composition or of especially close limits, is an intelligent one. It is quite in line with the "Simplification" program set up by Herbert Hoover when he was Secretary of Commerce, and which has been carried along by the Bureau of Standards ever since. There were eliminated odd sizes of tin cans, unusual loads in shot-gun shells, and the tag ends of many other commodities that had been asked for by purchasers without real necessity for just that size or grade, but which trade custom required producers to make and retailers to stock, even though there was so little call for them that their production involved a loss, since the producers and retailers didn't have the nerve to price them at the proper level.

The plan has been carried out by voluntary action, after full discussion and presentation of the needs of the consumer. It has worked well.

In the case of shot-gun shells, the hobbyist who wants an unusual load can buy empty shells, powder, shot, and a hand loading apparatus, and have fun evenings loading his own shells, analogous to the fly-tyer who started out by buying a farm so he could raise golden pheasants and have their feathers for use.

The user who wants a tailor-made wrought steel can't make it himself, it is none too easy to get it now, and it will be still harder when a list of "significant steels" is promulgated. The steel industry has been pointing with pride to the fact that this is the era of tailor-made steels. It would be foolish to try to throttle the development of better or cheaper

(Continued on page 172)

ARE YOU HELPING YOUR BUSINESS IN YOUR HOME?

DO you help the metal industry by promoting in your home the use of canned food and beverages? Time was when we often overlooked our mutual interest, but today when scientific research and the cooperation of metallurgists and canners have produced the perfect food container, it is time that we do our part.

This is important, not only to canners and steel mills, but to the entire metal industry. When canned food consumption rises, the buying power of growers and canning employees is increased; canneries require more building space and additional plant equipment, and suppliers use more metal parts and in turn buy more manufacturing equipment. An upturn in one branch of the metal industry benefits all.

We know better than most others, that in hermetically sealed tin containers are the purity, the freshness, flavor and healthful vitamins of the finest vegetables, fruits, and other food products as well as beverages. They are scientifically canned in their prime and perfectly preserved—always ready to be served without waste and at moderate prices.

So we urge you to help yourself and the whole metal industry by increasing the use of pure wholesome canned foods and beverages in your home. Inland Steel Company, 38 South Dearborn Street, Chicago. Sales Offices, Milwaukee, Detroit, St. Paul, St. Louis, Kansas City, Cincinnati.

SHEETS STRIP TIN PLATE BARS PLATES FLOOR PLATES STRUCTURALS PILING RAILS TRACK ACCESSORIES REINFORCING BARS

INLAND TIN PLATE

Produced only by the cold reduction method

Metals and Alloys in An Air-Conditioned Automobile

BY HERBERT CHASE

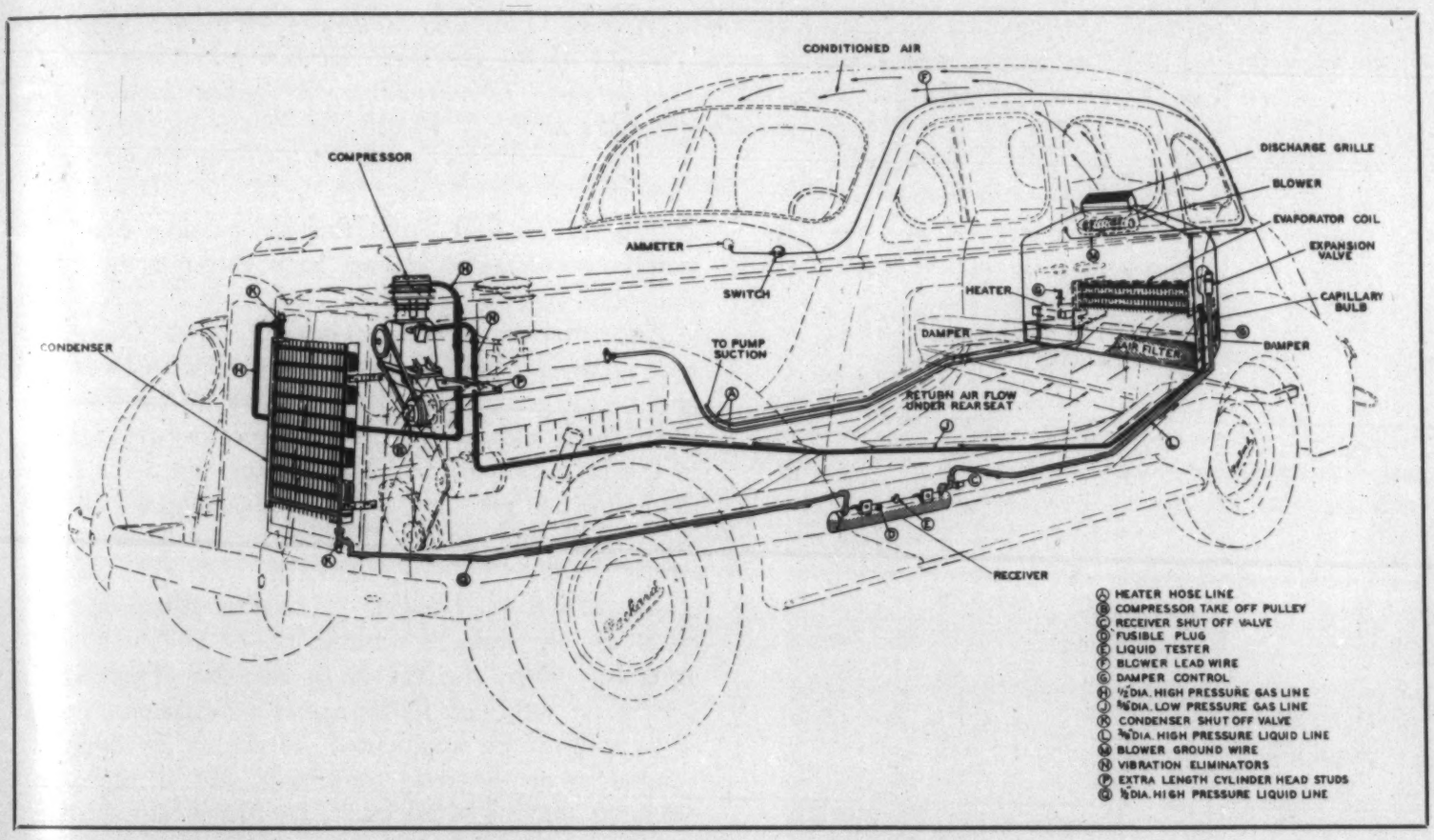
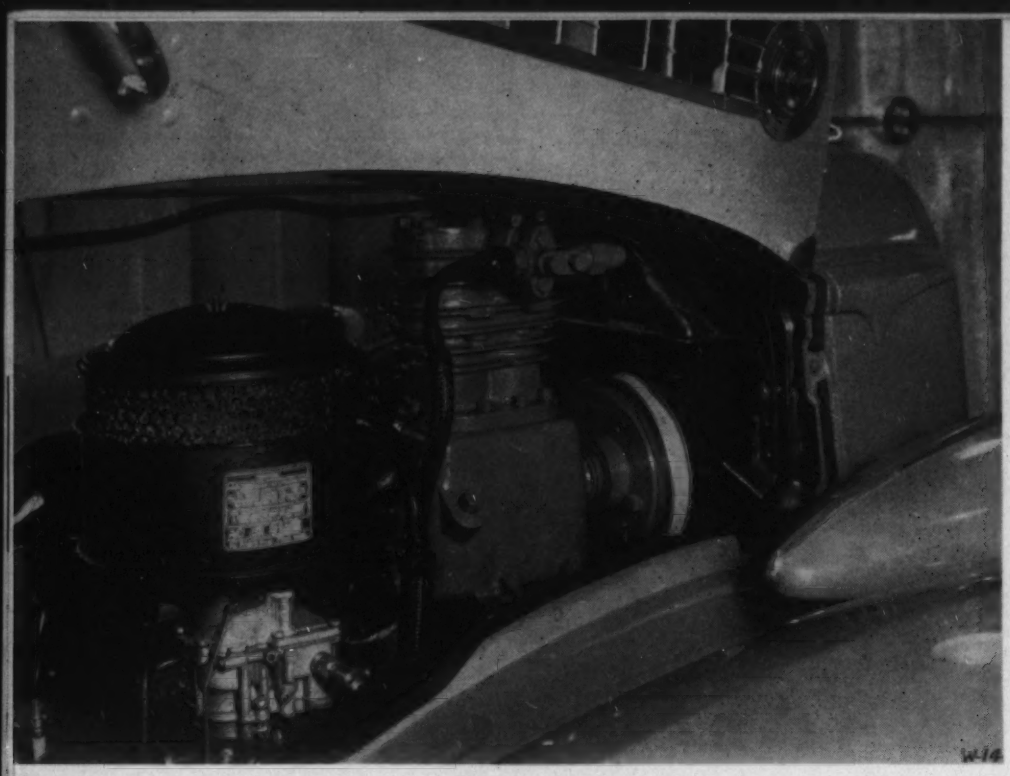
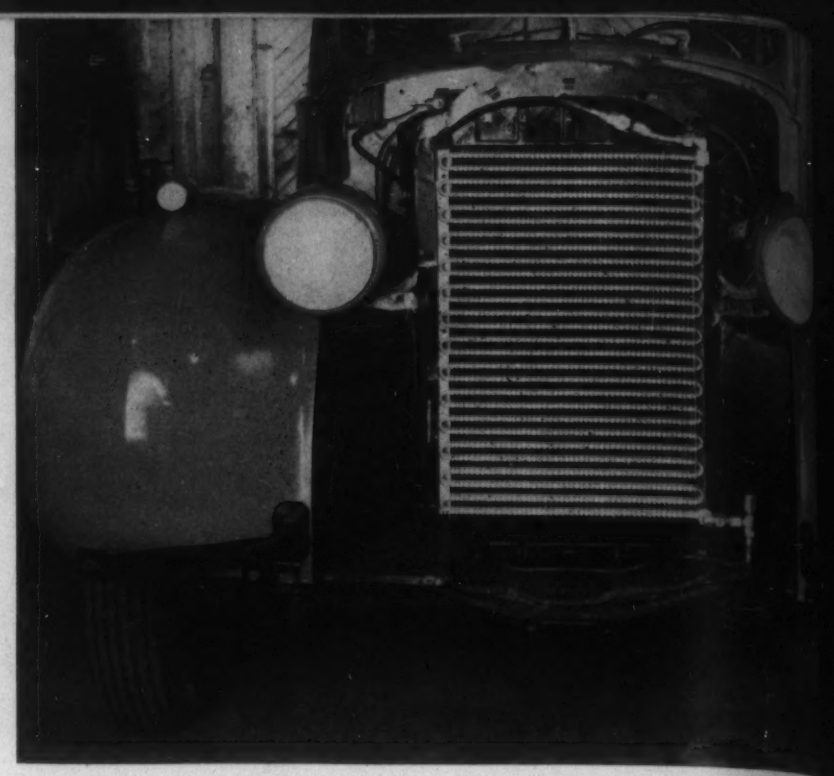


Diagram of the Packard system for a completely "weather conditioned" car, showing the location of the various units required for heating and cooling air and circulating it through the body of the car.

QUITE RECENTLY, the Packard Motor Car Co., Detroit, announced that its cars could be purchased equipped with a system of "weather conditioning" which, for the first time, in motor cars for private use, employs mechanical refrigeration for cooling in hot weather. Although much experimental work involving the use of refrigeration for making passenger cars more comfortable in summer has been done by other makers of automobiles, the Packard system is the first to be offered on a commercial scale as special equipment at extra cost.

In the Packard system, provision is made for circulating either cooled or warmed air through the car. The refrigerating system is designed, of course, for use in hot weather, and is put out of commission in cold weather. Provision for heating is required, naturally, only in cold weather and is put out of service when the weather is warm or hot. Heating is accomplished by a radiator through which hot water from the engine is circulated, as in conventional systems, except that the heater is located in a housing in the luggage compartment back of the rear seat and air is circulated by means of a blower





Close view (left) of the compressor used in the refrigerating system. This unit is driven by V-belt from the engine on which the compressor is mounted. Front view (right) of the car with radiator grille removed to show the finned-tube condenser into which the compressor discharges. The condenser is located between the grille and the radiator of the car.

of the sirocco type located at the top of the housing and discharging upward just aft of the back rest for the rear seat. This blower is driven by an electric motor controlled by a switch with a rheostat located on the instrument panel. In hot weather, the blower is used also to circulate air which has been cooled by passage over the evaporator of the refrigerating system, located in a second duct within the housing in the luggage compartment.

Equipment for Refrigeration

Mechanical refrigeration is effected by a piston-type compressor, similar to that used in household refrigerators but larger in size and having two cylinders. This compressor is mounted above the engine of the car and is driven by a V-type belt running over a pulley integral with that which drives the fan and water pump of the engine. The compressor draws the refrigerant gas, Freon, from the evaporator, compresses it to a pressure of 150 lbs. per sq. in. and delivers it through a valve into a condenser mounted back of the radiator grille and in front of the radiator of the car. In the condenser, the gas is cooled by air which circulates over the finned coils by reason of the forward motion of the car and of the draft created by the fan of the engine. Cooling of the gas results, of course, in reducing it to a liquid which is forced into a receiver located on the frame of the car under the left front door. From the receiver, the liquid is forced through a tube and expansion valve, the latter being located just outside the housing in which the evaporator is located but immediately adjacent to the evaporator. This completes the refrigerating circuit and the refrigerant, warmed and converted into a gas by absorption of heat from the air passing over the evaporator, is again drawn back through the compressor.

Air, whether cooled or heated, flows along the roof of the car and is subsequently drawn downward and back again under the rear seat by the blower, recirculated either over the evaporator or radiator in the rear compartment (depending upon the position of a damper) and is again discharged into the car. Thus, the system depends upon recirculation and is designed for use, normally, with all windows closed. There is, however, a considerable influx of fresh air by leakage around doors and windows, especially when the car is in motion. This air is said to be sufficient for adequate ventilation. Fresh air supply can be augmented, of course, by opening a window or the cowl ventilator, but if any considerable amount of air enters by this means, neither the cooling in hot weather nor the heating in cold weather will be sufficient if exterior temperatures are extreme. About one ton of refrigeration can be provided by the compressor at car speeds of around 25 m.p.h. and proportionately more or less in proportion at other speeds, since the compressor speed is proportional to that of the engine and of the car.

Metals and Alloys in the Equipment

Although the foregoing has little to do with the type of metals and alloys chosen for use in the system, it gives some idea as to the conditions under which the system functions and these in turn have a definite bearing upon the choice of these materials. The way in which the units are disposed in reference to the car is made clear by reference to the

Luggage compartment, showing the sheet steel housing in which the evaporator and the car heater are located. A partition divides the housing and a damper (with handle at lower right) can be set so that air entering the car is drawn over the evaporator when cooling is required or over the heater when the air is to be warmed.

Interior of Packard car, showing the die cast fitting through which air which has been heated or cooled is discharged by blower rotors located just below the fittings.

accompanying diagram of the system.

Considering first the compressor, which must be capable of operating dependably at high as well as at low speed and is subject to considerable vibration, it may be noted that its base is a high test iron casting which is chosen rather than ordinary gray cast iron because this permits of somewhat lighter weight combined with ability to withstand vibration and shock without danger of fracture. Compressor cylinders are also high test iron castings and are sufficiently resistant to piston wear to insure long life under high speed operation. Compressor pistons, too, are high test iron.

The crankshaft and connecting rods are of hardened alloy steel which has adequate strength and hardness to withstand the stresses imposed in high speed operation and to resist the wear resulting from the friction of main and connecting rod bearings which are of leaded bronze.

The compressor is supported on a bracket of malleable iron bolted to the cylinder head of the engine. To avoid the transmission of compressor vibration to and through tubing which connects to other units, this solid tubing is not fastened directly to the compressor, but there are short intervening sections of high grade flexible tubing having an inner wall of brass and an external covering of woven bronze wire. Mounted on the compressor crankshaft is a pulley having steel flanges and a malleable iron hub, a combination affording light weight, adequate strength and moderate cost along with sufficient hardness to avoid undue wear should belt slippage occur through failure to maintain

proper belt tension.

Copper and Steel Tubing

Tubing in the refrigerant circuit is of annealed copper, 5/8, 1/2 and 3/8 in. in diameter and is, of course, dehydrated to avoid the chance of water getting into the system where its presence would result in the formation of ice and perhaps tend to promote corrosion. This tubing is, of course, readily bent to the shapes required and is resistant to corrosion, besides being readily flanged for connection to valves and where other unions are required. As the refrigerant, Freon, is non-corrosive, no unusual precautions against corrosion of parts with which it comes in contact are required. Expansion and other valves, however, are of brass and have seats of bronze which are commonly classed as having high corrosion resistance.

Since the condenser is subject to high pressure and is in a location where a material as soft as copper might be injured by flying gravel or in some other manner, the tubing is seamless steel finned with steel. This combination produces adequate heat transfer and strength is ample to meet requirements. The condenser finish consists of tinning which forms a suitable bond and affords protection against rusting in an air stream which, of course, is frequently moisture laden.

The liquid receiver is of heavy gage seamless steel tubing (S.A.E. No. 1010) chosen for adequate strength and to resist abrasion from gravel which may cause abrasion in service. An enamel finish is applied over the exterior surface to help prevent corrosion.

Sheet Steel is Used

As above indicated, the evaporator is inclosed in a sheet steel housing in the luggage compartment of the car and is fastened against the sheet steel wall which separates the compartment from the car interior. The housing is of deep drawing auto body sheet which is tinned to resist corrosion and is sprayed outside with a finish containing rayon flock which gives a suede-like appearance, the same as that on adjacent luggage compartment surfaces. Tubes of the evaporator are of copper finned with copper, and tinned. This affords maximum heat transfer and gives excellent resistance to corrosion in contact with the moisture which collects (and is frozen on and afterward defrosted from) the tubes. The core of the heater is similarly constructed, using the same materials to afford high heat transfer.

Blower rotors are molded from Bakelite which, of course, is light in weight, not subject to corrosion and requires no applied finish. Its use is said to promote quiet operation and to insure well balanced parts which are quiet in operation. The blower discharges into an outlet fitting which is die cast in zinc alloy and painted. This metal and type of construction is chosen because it affords a part having the required symmetry for good appearance and to insure minimum resistance to air flow, combined with moderate cost and freedom from red rusting. In the mouth of the fitting are adjustable louvres die cast in zinc alloy which are given a painted finish for good appearance and resistance to corrosion. The louvres, of course, make it possible to direct the air steam in such a way as to secure the desired distribution of air without unpleasant drafts.

From the foregoing it will be apparent that the system does not make necessary the use of any unusual metals or alloys, which is a point in its favor, since this tends to minimize cost and in no way detracts from satisfactory performance. It is, of course, evident that those responsible for the design are acquainted with economic conditions which have to be given consideration when a new product is developed for manufacture without undue cost.

Hydrogen, Flakes and Shatter Cracks

A CORRELATED ABSTRACT - PART IV

Part 3: The Prevention of Defects Caused by Hydrogen in Steel

Flakes

The beneficial effects of aging, annealing and slow-cooling on flake-sensitive steels have been sufficiently discussed. In view of the trapping effect, however, it has been pointed out that, while a great amount of the hydrogen may be removed by proper heat treatment, heterogeneity of the steel will hinder this removal. It is fundamentally important, therefore, to consider methods of preventing hydrogen from ever entering the steel. Because molten steel dissolves several thousand times as much hydrogen as does cold steel, the steel-making process should be examined for possible sources of hydrogen. In this regard it is significant that steel made by some basic processes, notably basic electric, is consistently more flake-sensitive than other steels.

Bardenheuer[113] has pointed out that there is a great amount of water contained in rust, and that hydrogen may thereby be introduced to steel through additions of scrap and mill-scale. He calculated that a 1 per cent addition of rust to a 10-ton bath of steel introduces about 900 cu. ft. of hydrogen, measured under standard conditions. This quantity of hydrogen is 20 times the volume of the steel.[209] Also lime, particularly burned lime, avidly absorbs water and should be carefully dried before being added to the charge. Ferroalloys have been open to suspicion for hydrogen content, but tests with ferrosilicon have shown no noticeable influence on flaking.

The most obvious source of hydrogen is from the moisture in the air.[111] Chuiko and Lvova[216] found that flaking and similar defects varied in degree with the humidity. Rainy days had a particularly bad effect. Hays and Mikaloff[219] state that the moisture carried into a 1000-ton blast furnace with the blast varies from 72 gal. per hr. in the winter to 1100 gal. per hr. in the summer. In 1879, Müller[5, 11] suggested drying the air before using, both in the blast furnace and the open-hearth. Patented at that time in Germany, the suggestion has also been made recently by Herty.[97]

Investigations in Russia by Myrzymow, as reported by Hieber[220, 221] and the *Metallurgist*,[217] indicate that to remove hydrogen from molten steel a certain minimum amount of carbon must be eliminated during the boil, and that the refining period should be short. Definite evidence of a relationship between melting procedure and sensitivity to flaking was found. Two thousand melts were made of ball-bearing steel analyzing:

	Type A	*Type B*
C	0.95 to 1.1	0.95 to 1.1
Si	0.15 to 0.35	0.15 to 0.35
Mn	0.25 to 0.40	0.20 to 0.40
P	less than 0.027	less than 0.027
S	less than 0.02	less than 0.02
Ni	0.2	0.2
Cr	0.75 to 1.05	1.30 to 1.65

Eight- and 15-ton basic electric furnaces were used. One-fifth of the melts were made from scrap, the remaining from pig iron and ore. Of the scrap-made melts, 26.2 per cent flaked, whereas only 18.6 per cent of the pig iron melts flaked.

Fig. 19 shows the relation, determined by Myrzymow, between susceptibility to flaking and the period of the boil. A boil lasting from 50 to 60 min. is optimum. The increase of flaking with longer periods is not necessarily significant, as Myrzymow mentions furnace defects.

Fig. 20 shows the relation of carbon elimination to flaking. If less than 0.5 per cent carbon was

by C. A. ZAPFFE and C. E. SIMS

Research Associate and Supervising Metallurgist, Respectively, Battelle Memorial Institute, Columbus, Ohio.

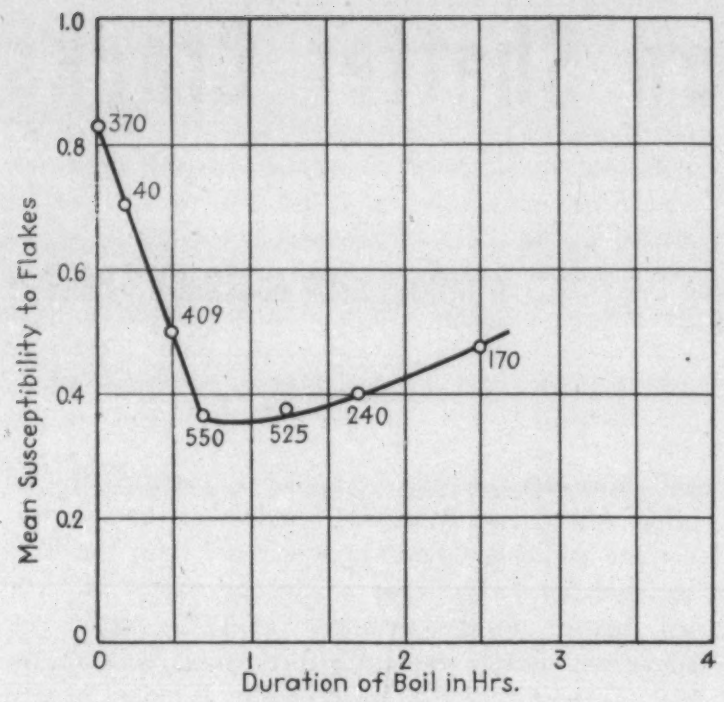
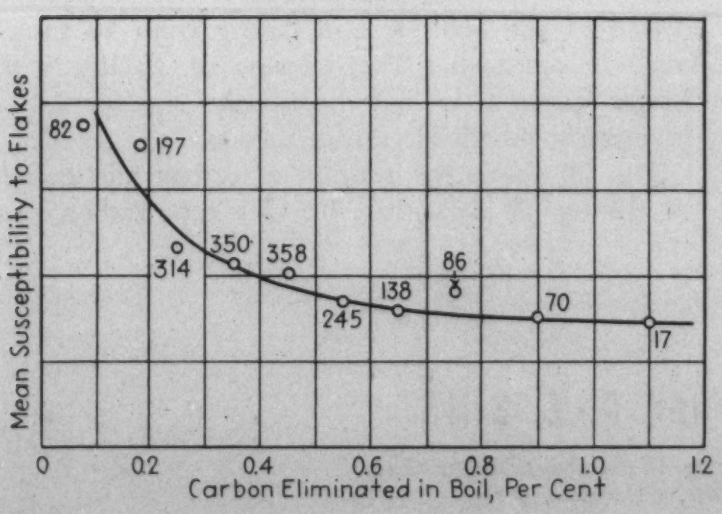


Fig. 19. Variation of flaking with duration of the boil. (Myrzymow)

eliminated during the boil, the flaking increased significantly. This effect can be explained as removal of hydrogen by the ebullient carbon monoxide. A natural activity here, it simulates the artificial method of removing hydrogen from molten steel by bubbling an inert gas through the melt.[113] The bubbles sweep out the hydrogen as they pass through the steel by virtue of the difference in the hydrogen pressures in the melt and in the bubble.

Chuiko[215] also reports that hydrogen is not removed when the carbon elimination rate is less than 0.1 per cent carbon per hour, and he states that a rate of 0.2 to 0.3 per cent C per hour can be recommended for acid open-hearth practice without danger of over-oxidizing the metal. Study of a large number of heats showed that hydrogen was continuously removed during boiling at a rate proportional to the hydrogen content. With low rates of carbon

Fig. 20. Variation of flaking with carbon elimination. (Myrzymow)



elimination, the hydrogen content of the furnace atmosphere varied from 1.8 to 26.4 per cent. Acid electric steel contained from 0.001 to 0.0017 per cent H_2 after melting down, and from 0.0006 to 0.0008 per cent H_2 at the end of the boil. In basic electric steel the hydrogen content was somewhat greater.

Kobayashi's[200] hydrogen analyses show that in acid open-hearth steel the hydrogen content begins to increase at the end of the oxidizing stage, becoming more noticeable at the killing period and after being tapped. In the arc furnace there is an increase during reducing and after tapping.

According to Hieber,[221] Myrzymow found that prolonging the refining period always increased flaking, as shown in Fig. 21. This is to be expected, as the de-gassing has ceased and gas enters the melt from ferroalloys and the newly-formed slag. Because the solubility of hydrogen in steel is greatest when the steel is molten, holding the metal liquid for prolonged periods can only result in increased absorption of the gas, other things being equal. Fig. 22 combines Figs. 19 and 21. The amount of inclusions present was found to vary much in the same manner as the flaking. That is, the procedure giving the least amount of flaking also lowered the inclusion count, or, at least, did not increase it.

Zamorujev[157] draws a similar relation between inclusions and flakes. According to this investigator, the steel-making process for flake-free steel must permit deoxidation under physico-chemical conditions so carefully controlled that the bath is not enriched with included matter. Slag deoxidation is preferable, as the addition of deoxidizers must be made too late to favor clean steel. Because basic open-hearth slags are not suited for deoxidizing, the charge in that process should contain 1.25 to 2.6 per cent Mn, and this should not be allowed to drop below 0.30 per cent at any time. At a late stage there should be a boil so active that the oxygen supplied by the flame is insufficient to carry the reaction and oxygen is taken from both slag and metal; after the boil, close the doors, make the flame neutral or slightly reducing, and then add pitch and 1.0 to 1.5 per cent (of heat weight) of calcium carbide to the slag. When the greatest possible deoxidation is obtained, bring the silicon content to 0.10 or 0.15 per cent by adding complex deoxidizers. Tap 30 to 40 min. later, killing the heat with aluminum. No ore should be added later than 1½ hrs. before tapping.

The acid open-hearth process responds more readily to methods for flake prevention. Zamorujev[157] proposes three methods: (1) Mild reduction with silicon (under 0.10 per cent), controlled according to temperature, with a 5 to 10 per cent CaO and 50 per cent SiO_2 slag; (2) partial reduction with silicon (0.10 to 0.13 per cent), requiring a previous strong boil with residual manganese not less than 0.30 per cent (1.5 per cent in charge); and (3)

reduction with 0.25 to 0.30 per cent silicon, using an average charge, without ore, and keeping the temperature as high as possible after melting down. Besides carbon elimination, there is silica reduction that provides as much as 0.30 per cent silicon if the temperature is high and the slag is 50 to 52 per cent silica. The bath is quite dead at this time, beginning the period of stabilization. Lower the temperature and keep the bath in the furnace for 2 hrs. to permit included matter to float. If this stabilization period is omitted, a 2- to 4-hr. boil is necessary with 2.5 per cent carbon in the charge.

Before hydrogen had been proposed as the cause of flaking, Metan'ev, Meshchaninov and Bizer[118] had found that to avoid flaking in the SAE 3312 type of steel the melt should be thoroughly deoxidized before ferroalloys are added, mixed well, poured at 1420 to 1450 deg. C., slowly cooled and annealed between 300 and 700 deg. C.

The procedure to be followed for preventing the formation of flakes in steel, according to the foregoing observations, may be briefly summarized as follows:

(1) Select a charge that is free from moisture and rust. The calcined lime used for the final slag in the basic electric furnace undoubtedly accounts for the fact that steels made by that process show the greatest tendency to flake. The lime should be carefully dried and stored in moisture-proof containers. Ferroalloys, especially if they are to be added late in the heat or in the ladle, should be dried before using.

(2) In processes requiring a draught or blast of air, dry the air before using. If the air is not dried, melting in humid or rainy weather will be especially unfavorable.

(3) Use a vigorous boil lasting about 1 hr., according to Russian work. The rate of carbon elimination should not be less than 0.1 per cent per hr. The acid open-hearth will perhaps permit a rate of 0.2 to 0.3 per cent per hr. without over-oxidizing the melt. A total elimination of 0.5 per cent is optimum. High temperatures are recommended by the British.

(4) Shorten the refining period. Avoid late additions to the bath. Tap at the lowest feasible temperature, according to the British and the Germans.

(5) Avoid mold washes that contain hydrogen. The shape of the mold is without influence.

(6) Pour slowly and prevent splashing and foaming. Bottom pouring is recommended.

(7) Strip the ingots at about 600 deg. C. (1100 deg. F.) and place them in the soaking pit until they are uniformly heated to the forging temperature; or, if they are not to be forged immediately, bury them, after stripping, in ashes, slag wool, charcoal dust, or some other insulating material, and let them cool slowly almost to room temperature. Hot-working before cooling is beneficial.

(9) After forging, cool the material in the manner just stated, being particularly careful that the cooling rate is exceedingly slow through the temperature range where the steel is no longer plastic. This precaution is important not only because both the solubility and diffusibility of hydrogen decrease with decreasing temperature, but also because internal stresses are only slowly relieved at temperatures below about 400 deg. C. The ends of forgings that are too long to finish in one heat are apt to cool to the flaking temperature. Some insulating wrapping on these ends will prevent this.

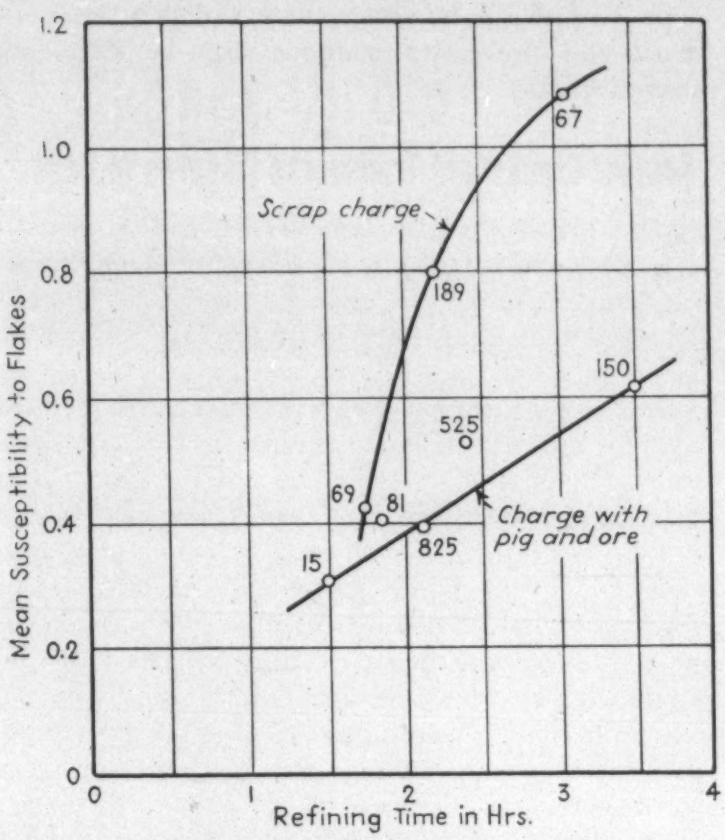
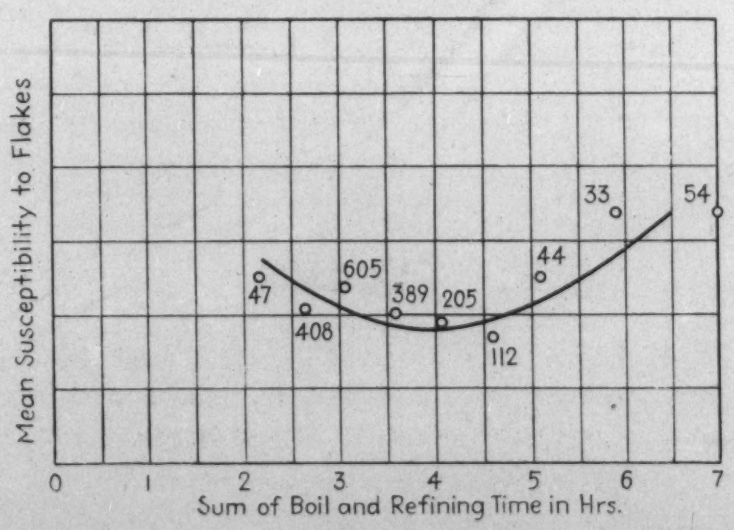


Fig. 21. Variation of flaking with the refining period. (Myrzymow)

The critical rate of cooling necessary for avoiding deleterious effects of hydrogen is obviously different for different specimens and is therefore best determined empirically for each type of product. Although the rate of diffusion is primarily a temperature function, the quantity of gas in the steel, and the nature and the degree of occlusion, depend upon the previous treatment of the steel. The optimum cooling rate is stipulated by the uncalculable variables of pressure and volume of the occluded gas, area and shape of the inhabited voids and the probability that the gas leaving the voids will reach the external surface of the specimen. For a given process and

Fig. 22. Variation of flaking with total boiling and refining periods. (Myrzymow)



type of product, however, these variables are quite fixed and preventive methods may be developed experimentally.

Shatter Cracks and Transverse Fissures in Rails

The situation regarding shatter cracks in rails is closely analogous to that of flakes and is perhaps of greater economic importance. Howard[26, 46, 55] had ascribed the early cases of transverse fissures to excessive wheel loads. As knowledge advanced of the mechanism of fatigue, however, it became evident that the true explanation requires high wheel loads exerted upon steel containing pre-existent nuclei, and that shatter cracks are such nuclei. It took a long time to prove that shatter cracks exist in some new rails, and a longer time to get rail-makers to accept this proof. Before this fact was completely accepted, it was found experimentally that, by slow cooling, shatter cracks could be avoided.[149] Although the optimum cooling conditions are still subject to dispute, slow-cooling methods are in universal use in the manufacture of American rails.

From the foregoing discussion of flaking it should be evident that hydrogen is the primary cause of shatter cracks. It is not necessary to make such an assumption, however, for independent experiments have been made on rail steel itself. Cramer and Bast,[232] and those discussing Cramer and Bast's paper, present sufficient evidence that hydrogen is mainly responsible for the appearance of shatter cracks.

The very obvious goal of avoiding hydrogen pickup during the melting of rail steel, or of so treating the melt that hydrogen already present will be removed, has not had much published discussion to date. Nevertheless, some rail-makers,[230] at least, are alive to this, and take great pains to avoid rusty or oily scrap, hydrated lime, and other sources of hydrogen in the charge; to boil in a manner favoring removal of hydrogen; and to carry the slag and direct the flames with intention to protect the bath from the water vapor that results from combustion of the fuel. Greater efforts to avoid introducing hydrogen may be expected as the realization grows that hydrogen is the cause of some of the ills of solid steel. Throughout the field of non-ferrous metallurgy there is a similar awakening to the defects that travel in the train of hydrogen.

Conclusion

Hydrogen only dissolves in steel atomically—in comparatively large quantities at high temperatures, and in negligible quantities at low temperatures. A decrease in the solubility causes a precipitation of molecular hydrogen which, if the precipitation occurs at a discontinuity within the steel, may develop local aerostatic pressures sufficiently great to cause fissuring. Theoretically, unlimited pressures of molecular hydrogen may obtain within a discontinuity. It has been demonstrated that pressures from 60,000 to 140,000 lbs. per sq. in., which are rupturing pressures, are necessary to force molecular hydrogen through steel, and a pressure of 4500 lbs. per sq. in. has been generated experimentally by hydrogen diffusing into steel from a pickling bath.

This unusual behavior of hydrogen accounts for numerous types of defects in steel. Whether other stresses contribute or not, it is true that hydrogen can cause flaking, shatter cracks and embrittlement with their attending phenomena. It is probably also true that this gas causes or aggravates numerous types of intercrystalline failures, hot shortness, red shortness, welding defects and blemishes in coatings on steel.

By understanding the fundamental features of the Iron-Hydrogen system and the nature of the complications attending alloying iron to make steel, it is possible to avoid these defects. As prevention is the best cure, it is most advisable to guard the steel against excessive hydrogen pickup during the melting procedure.

The conception of embrittlement seems to be more nebulous than is warranted by the data available. The agency appears clearly mechanical, operating in the same manner as flaking and other defects that are attributable to occlusion of molecular hydrogen under high pressure. Inability to observe the minute and highly dispersed discontinuities active in embrittlement has strengthened the unlikely argument that embrittlement is due to the formation of iron hydride. As the evidence favors instead the mechanical picture, an interesting commentary on the fine-structure of metals is provided.

To explain the rapid effect of aging and low-temperature annealing on the escape of molecular hydrogen from ultra-microscopic cavities, it seems helpful to postulate that occlusion of hydrogen in such cavities is more reversible than occlusion in visible cavities. Between the converging rows of atoms that would exist in fine-structure disjunctions the adsorbing forces might be markedly stronger, whereby the partial pressure of atomic hydrogen in the discontinuity is increased above the norm, causing greater solution of atomic hydrogen around each rift and consequent greater escape.

There is yet much to be learned regarding the effects of hydrogen on steel. The present writing has only attempted to integrate and rationalize existing data and to point out the pronounced influence that hydrogen exerts on steel.

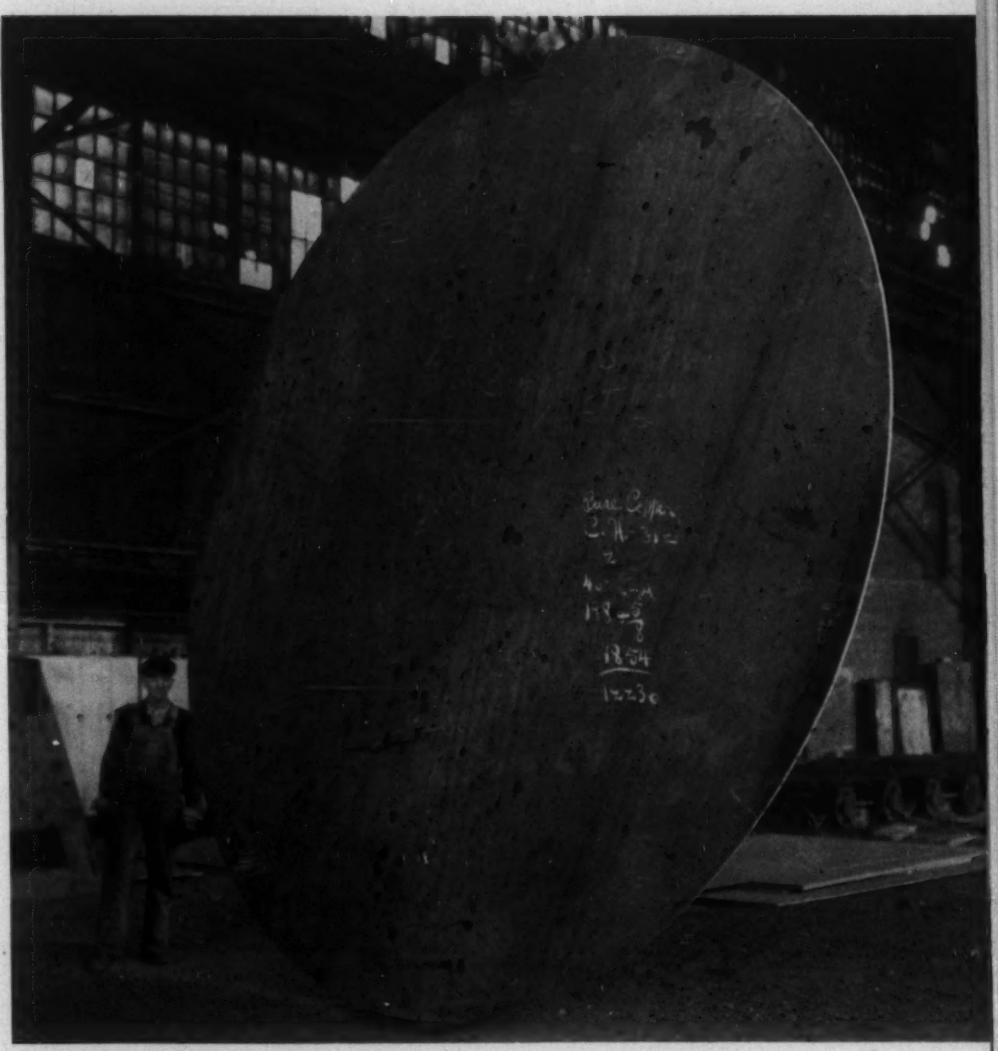
Rolling World's Largest Copper Circles

FOUR ONE-PIECE, circular copper plates, 16 ft. 6 in. in diameter, undoubtedly the largest ever rolled in solid copper, were produced recently on the 206-in. rolling mill of the Lukens Steel Co., Coatesville, Pa., for Revere Copper & Brass Inc., New York.

In contrast to the rectangular ingots from which steel plates are rolled, these copper circles were rolled from circular slabs or "cakes," furnished to Lukens by the Revere Company. All four of the copper "cakes" were 4 ft. 8 in. in diameter, two being 10 in. in thickness and weighing 7,886 lbs. each, and the others being 8¼ in. in thickness, weighing 6,218 lbs. each.

Converting the circular "cakes" into plates, two ⅝ in. thick with finished weight of 6,870 lbs. each—one of which is shown in one of the illustrations—and the others to ½ in. thickness and finished weight of 5,594 lbs. each, was a tricky job.

In rolling, the diameter of each cake had to be extended uniformly around the circumference, while at the same time, the gage of each plate had to be maintained within narrow limits. After rolling, the copper circles were annealed and pickled by Lukens before shipment.



Right: One of the largest plates ever rolled in solid copper is this plate 16 ft. 6 in. in diameter, ⅝ in. thick, weighing 6,870 lbs.

Rolling a copper cake, 4 ft. 8 in. in diameter, 10 in. thick, into a circular plate, 16 ft. 6 in. in diameter, ⅝ in. thick, on the Lukens 206-in mill. After nearly every pass through the mill, the cake was turned to insure uniform expansion.

Pearlitic Malleable fr

IN THE PRODUCTION OF MALLEABLE IRON in the United States, "there is a limited use for cold melting in electric furnaces," according to H. A. Schwartz in the Metals Handbook for 1939. Electric furnaces are used in both duplexing and triplexing but by far the great bulk of malleable castings, whether ordinary or pearlitic, is made from material melted in the conventional air furnace.

Not long ago we had the opportunity of visiting the foundry of one of the leading American producers of malleable iron castings. While most of the castings of the regular grade made by this company are melted in three large 20-ton air furnaces, fired with powdered coal, we were impressed with the extent to which the electric arc furnace is used to make special grades, including pearlitic malleable.

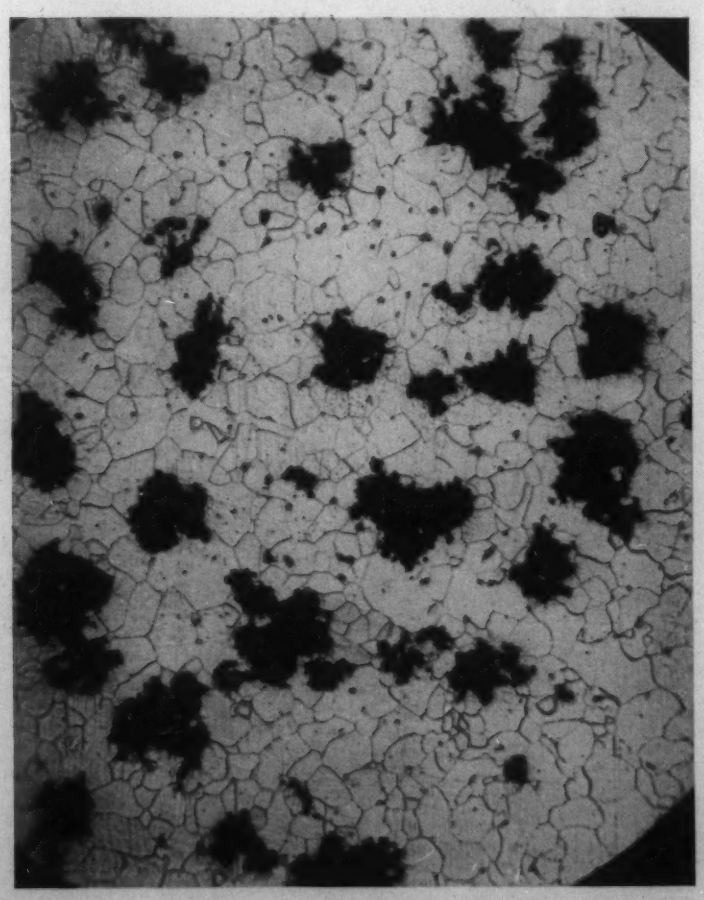
It is believed by the officials of this company—the Belle City Malleable Iron Co., Racine, Wis.—that their organization is the only large one in this country which is producing pearlitic malleable and a special grade of high tensile malleable from a cold melt in an electric arc furnace. Whether or not this is true, the metallurgical account of the application of the electric arc furnace in this foundry is interesting.

Pearlitic Malleable Defined

The definition of pearlitic malleable iron by Schwartz is: "White cast iron subsequently graphitized by heat treatment so as to intentionally leave significant amounts of carbon in the 'combined' or 'agraphitic' form." This is accomplished by any one of the following three methods: (1) Special heat treatment of the castings, by whatever method melted so as to arrest graphitization, or by completely graphitizing and then recombining some carbon; (2) by a combination of alloys and special heat treatment; and (3) by alloys which fit into the regular annealing.

The usual retarding alloying elements, according to Schwartz, are "manganese in an amount up to 1 per cent or more than the concentration otherwise

Structure (left) of regular malleable iron at 150×. The structure of Belmalloy at 150× at right. Nodules of temper carbon are sparsely scattered in a matrix of laminar pearlite, stronger, tougher and harder than the ferrite of malleable iron.



from the Electric Furnace

by EDWIN F. CONE

suitable for normal malleable; chromium often in low concentration of 0.10 to 0.25 per cent but occasionally suggested higher; and molybdenum seldom up to 1 per cent and frequently about 0.25 per cent or even less. Some see virtue in the combined use of rather large amounts of retarders and additional accelerators, as for example, silicon with chromium or molybdenum."

It should perhaps be said here that the term pearlitic malleable has been adopted "even though not precisely justified metallographically since the prevailing structures are laminated or granular pearlite and sorbite between which definable distinctions are difficult to make, at least simply."

In the Electric Arc Furnace

All of the pearlitic malleable iron castings of the Belle City company are made from a base metal made in an electric arc furnace, instead of being melted in the air furnaces generally used elsewhere for regular malleable and most of the pearlitic malleables. It is generally recognized that the electric furnace is unequalled as a means of closely controlling the composition so essential for securing a metal that will respond uniformly to heat treatment, whether it be for steel castings or malleable.

The product made by the Belle City company—known to the trade as "Belmalloy"—is produced by the third method for making pearlitic irons outlined above, i.e., by adding alloys which fit into the regular anneal and which retard the graphitization. The alloys used in this case are manganese and molybdenum in about the proportions indicated by Schwartz. The fact that these are added to the base metal in the electric furnace bath, and not in the ladle, is pointed to as insuring uniformity. Where alloys are used in the air furnace metal, they are usually added to the ladle.

Dressler Kiln for Annealing

But a uniform base metal is not the only requisite. There must be uniformity in the annealing. For all the malleables of the Belle City company a Dressler continuous kiln is used. The Dressler Tunnel Kiln, used at this plant, is 350 ft. long and is of the muffle type and continuous in its operation. There are said to be less than 10 in the country's founderies. It is pointed out that the positive and accurately controlled heat treatment received in this furnace makes certain the complete conversion of the hard, massive

Tapping a heat of malleable iron from one of the arc electric furnaces at the Belle plant.

cementite of the white iron into pearlite and temper carbon and the relieving of internal stresses in the castings. The relief of internal stresses is said to insure freedom from distortion in use.

Photomicrographs of regular malleable and of Belmalloy at 150X are presented and the Table gives the average physical properties of the final product. In the structure of the pearlitic malleable, as made by alloying the metal in the electric furnace, it will be noticed that the nodules of temper carbon

Table of Physical Properties of Belmalloy, Regular Malleable and Steel Castings

	Belmalloy, Pearlitic Malleable	Regular Malleable		Steel Med. A.S.T.M.
		32,510*	35,018*	
Tensile strength..	70 to 80,000	50,000 to 52,000	53,000 to 60,000	70,000 min.
Yield point.....	45 to 50,000	32,500 to 35,000	35,000 to 40,000	31,500 min.
Shear strength...	60,000	46,000	51,000	69,000
Elongation, per cent	5 to 10	10 to 18	18 to 25	20 min.
Brinell .....179 to 207		105 to 135	125 to 143	147 to 169

* Specifications from Cast Metals Handbook.

are sparsely scattered in a matrix of laminar pearlite, stronger, tougher and harder than the ferrite of regular malleable iron.

The annealing cycle in the Dressler kiln is as follows:

30 hrs. to 1700 deg. F.
35 hrs. soak at 1700 deg. F.
20 hrs. cool to 1370 deg. F.
Cool 4 deg. F. per hr. down to 1100 deg. F.

A High Strength Malleable

Another interesting malleable iron product, made by this company, entirely from a cold melt in an electric arc furnace is a high strength malleable iron which has been named "Belectromal." The usual charge for any malleable iron is used as in the case of the alloy just described, and certain percentages of copper and molybdenum are added. Like the pearlitic Belmalloy, the composition has the usual percentages of carbon, manganese, silicon, sulphur and phosphorus for malleables, plus a little copper and a smaller amount of molybdenum to refine and strengthen the ferritic matrix and to reduce the size

The malleable iron foundry is large, roomy, orderly in layout, with wide aisles and efficient lighting.

This 100 - ton Oilgear Press straightens certain castings between dies.

and dispersion of the temper carbon nodules.

This product, again a uniform base metal electrically melted and uniformly annealed in the Dressler oven, has the following physical properties:

Tensile Strength	—60 to 70,000 lbs. per sq. in.
Yield point	—45,000 lbs. per sq. in.
Elongation	—15 to 20 per cent
Brinell	—145 to 170

It will be observed that, compared to regular malleable, this product has higher properties.

In the production of both of these special alloy malleable castings, the combination of electric melting and tunnel kiln annealing are considered of prime metallurgical importance. A uniform base metal and thorough uniformity in annealing are assured—both essential in the production of a high grade product.

We have made a partial survey of those malleable foundries which were said to use electric furnaces for melting from a cold charge. We located only one, other than the Belle City foundry, which so operates. Silicon and manganese alloys are used and the castings are annealed in Hevi-Duty electric furnaces in this other plant. Malleable scrap with additions of alloys for a result of C 2.10 to 2.25, Si 1.40 to 1.50 and Mn 0.30 to 0.40 per cent is the practice and the bath is superheated to 3200 deg. and poured at 2900 deg. F. There are no additions of copper or molybdenum. The castings are placed in boxes and are held for annealing at 1800 deg. for 14 hrs., then cooled to 1275 deg. F. Evidently this product is not a pearlitic malleable.

The manufacture of pearlitic and high strength malleable irons from a cold melt with the addition of alloys is apparently confined to the Belle City company.

The Dressler continuous tunnel type kiln is operated with clocklike regularity and performs the annealing process with efficiency and uniformity.

Dumping annealed castings from the pots. Electric cranes serve this 500-ft. building.

PART 2: CONCLUDED FROM JULY

Powder Metallurgy of Copper

Impurities

Three types of impurities were found in the finished compacts: (1) Thin films, (2) small inclusions, and (3) incompletely reduced cuprous oxide.

The most frequent occurrence of impurities was in thin films and fibres at the grain boundaries. Their origin can be traced back to oxide or grease films which were formed around the initial powder particles. A careful treatment of the powder at about 300 deg. C. in hydrogen before compacting removed most of the oxides, but did not completely remove carbonaceous matter. There is little doubt that these films of impurities hamper diffusion to a great extent, and have a marked effect on the malleability, ductility and impact resistance of the compacts.

Another type of impurity, found almost exclusively in compacts made from the reduced copper powder, appeared as bulky cuprous oxide particles. In contrast to the oxide films around the particles, these products of incomplete reduction were rather hard to remove. If their removal was accomplished during sintering, they usually left numerous irregular particles of impure copper in their place.

Compacts made from the reduced powder, while of lower ultimate strength than those of the finer electrolytic powders, nevertheless displayed better rolling ability. This indicates that the isolated inclusions of spherical shape had less effect on malleability than film-like impurities.

Heat Treating Atmosphere

The results of the physical tests indicated a certain superiority of all vacuum-sintered specimens, as compared with those heat treated in hydrogen. The results of the rolling tests, tension tests, impact tests, and, particularly of the bending tests made on compacts, demonstrate this. On the other hand, the metallographic investigation disclosed that the structure of the hydrogen-treated material more closely approaches the structure of cast copper than does that of vacuum-sintered compacts (compare Figs. 5 and 6). The latter specimens showed an extremely large amount of small spherical cavities at the grain boundaries, particularly if the compacts were produced from the finer powders. Only after a second pressing and sintering operation, did the material assume an appearance similar to that of hydrogen-treated compacts. Even in consideration of the fact that the pores of the vacuum-treated compacts were more regular, and therefore presumably less harmful than in the hydrogen-treated compacts, some striking differences in the above-mentioned properties of the two types of sintered compacts can hardly be explained. Vacuum-sintered compacts made from the finer powders, even when molded at low pressures, showed much greater bending capacity when compared with hydrogen-treated compacts of similar or even higher density (Fig. 3).

There are two important factors that might account completely for the observed effects: one is the well-known hydrogen-embrittlement of copper, and the other is the presence of fine films of a carbonaceous grease residue at the grain boundaries.

Hydrogen-embrittlement of copper is generally explained by the reaction of hydrogen with cuprous oxide during annealing at elevated temperatures. In the case of sintered copper, the distortion resulting from the steam formed is likely to be less pronounced, since the entire metallic substance in the compact is not so impervious as is "gross" copper, and provides ample possibility for passage of the gases without excessive distortion of the structure. On the other hand, there is little doubt that embrittlement occurs to some extent during heat treatment of the specimens in hydrogen. Evolution of steam in the early stages of hydrogen-sintering could be noticed, even when the gas was carefully dried before entering the furnace. The inferiority of the hydrogen-treated compacts as compared to vacuum-sintered compacts gradually disappears with an increase in the duration

by CLAUS G. GOETZELL

Ass't. Director of Research
American Electro Metal Corp.
Yonkers, N. Y.

of heat treatment; however, the time necessary for the production of an adequate compact by hydrogen-treatment is about ten times greater than in the case of vacuum-sintering, and only a period of annealing extended over several days finally permitted all the gas to escape, and removed the strains.

This type of embrittlement may not be the sole reason for the superiority of the vacuum-sintered compacts. Determinations of the weight losses during heat-treatment of the compacts disclosed that certain impurities were removed during vacuum-sintering that were not removed when the compacts were treated in other atmospheres. The improved ductility of vacuum-sintered specimens might be attributed to the removal of these impurities. Grease, possibly originating in the electrolytic cells, or becoming attached to the particles during handling, could be almost entirely removed in vacuum-sintering, but not in other atmospheres.

Pressing and Sintering

In cold-compressed compacts, not subjected to heat-treatment, the bond between the particles may be attributed to adhesion forces. It is possible, though as yet not proved, that pressures such as those employed in this research may cause enough local heat of friction between the particles to bring about boundary diffusion between them. On the other hand, the author's observations prove that grain growth was preceded by recrystallization, which certainly cannot be expected during the application of the cold-compression operation. If boundary diffusion, sometimes called "atomic welding," is really achieved during compression of the particles, then it certainly can only be of a superficial nature, since the cold-compressed compacts are extremely brittle and weak. (Some properties of such compacts are given in Fig. 8.) This is supported by the presence of angular porosity, due to over-bridging of the particles, particularly if they are odd-shaped as in the electrolytic type of powder. These cavities lower the values of the electrical conductivity and all mechanical properties extremely, with the exception of hardness, which is much dependent upon the degree of straining to which the compacts were subjected.

The effects of the many variables in the manufacture of sintered copper compacts on their shrinkage and on final properties are given graphically in Figs. 8 to 10.

The values of elongation and impact resistance (see Fig. 8) of sintered (heat-treated) copper were generally low. This may be attributed to particular conditions at the grain boundaries. Even compacts twice treated most carefully for long periods in vacuum still showed a definite lack of ductility and plasticity, although much of the impurities had been removed by evacuation.

The sintered copper showed better malleability and ductility under a static compression load than under tension (Fig. 8). This is to be expected if one considers the peculiar structure of the sintered material with its porosity and contaminated grain boundaries. In close agreement with this was the weak impact resistance of the sintered copper compacts. Electrical conductivity was below the standard specifications for "gross" copper. An increase of electrical resistance is the logical consequence of the cavities and impurities scattered at the grain boundaries. Hardness was only slightly affected by the porosity present in the compacts, but was chiefly dependent upon the strain-condition of the compacts.

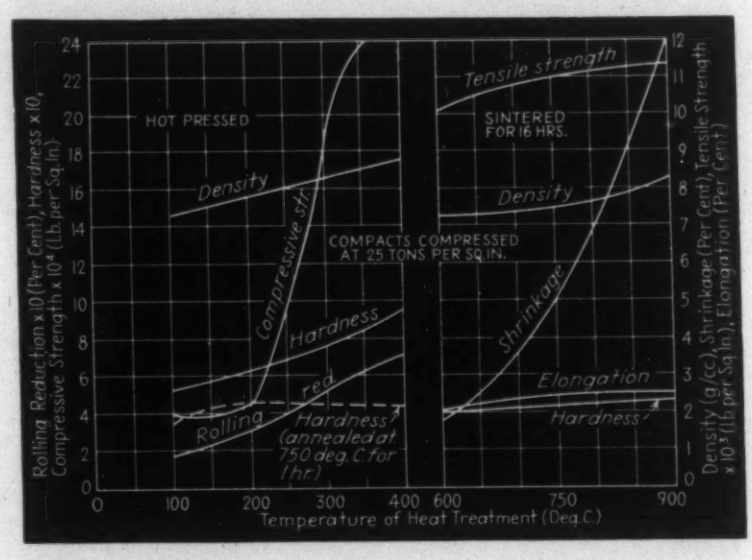


Fig. 9. Effect of temperature of treatment on the properties of hot-pressed and of sintered compacts made from electrolytic copper powder C.

Only in very porous specimens, soft or strained, was the hardness below the value of cast copper. In dense compacts, previous straining governed the hardness entirely.

Some results of the fatigue tests (Fig. 11) were striking: Imperfections, such as pores or deteriorated grain boundaries have always been considered detrimental to the resistance of a metal to fatigue as fatigue failures usually are expected to start from these imperfections. Yet sintered copper with its numerous cavities showed a fatigue resistance similar or even superior to that of cast oxygen-free high conductivity copper.[16] This establishes a close relationship of the fatigue values with those of tensile strength, which also reached or slightly exceeded that of cast oxygen-free high conductivity copper.

Hot Compressing

In order to obtain maximum values of hardness and strength, the initial powder must be fine, and must be compacted at high pressures. The tendency

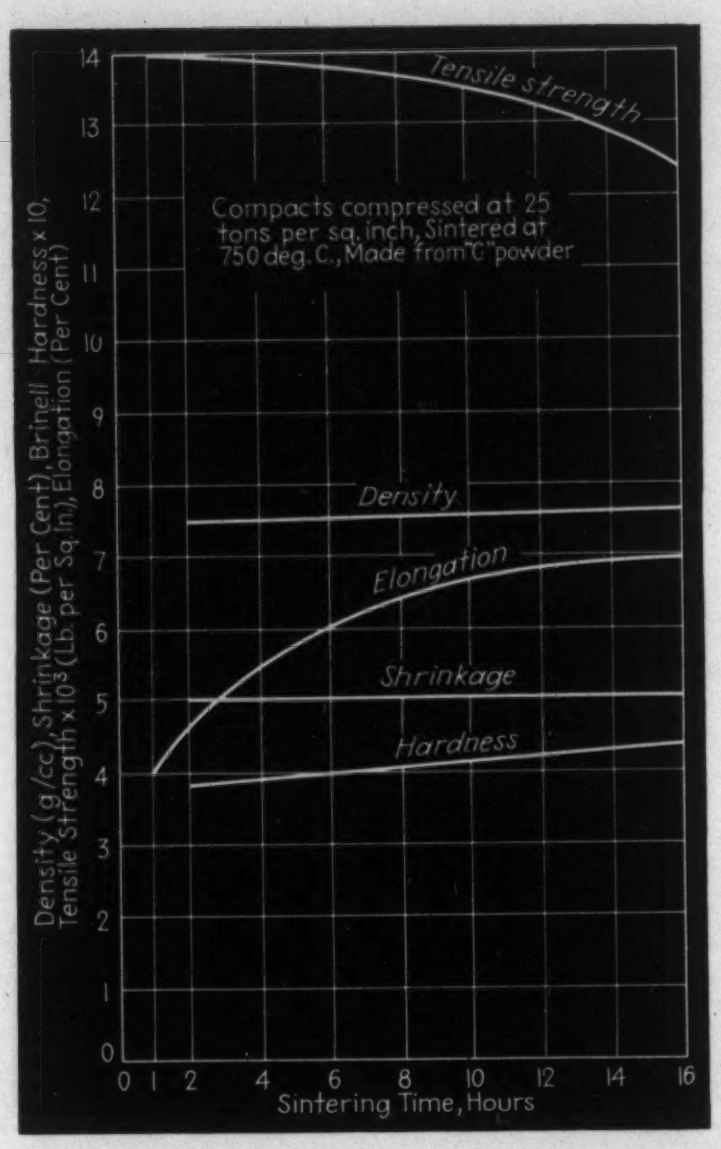

Tensile strength
Compacts compressed at 25 tons per sq. inch, Sintered at 750 deg. C., Made from "C" powder
Density
Elongation
Shrinkage
Hardness
Density (g/cc), Shrinkage (Per Cent), Brinell Hardness x 10, Tensile Strength x 10³ (Lb. per Sq. In.), Elongation (Per Cent)
Sintering Time, Hours
0 1 2 4 6 8 10 12 14 16
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Fig. 10. Effect of sintering-time on the properties of sintered compacts made from electrolytic copper powder C.

to entrap air sets a limit to the fineness of powder and to the compacting pressure, and porosity from this cause can be reduced only if compression of the powders is carried out at elevated temperatures, thus taking advantage of the increase of plasticity of the material. A general description of the hot compressing method employed has already been given.

The density of hot compressed specimens, as shown in Fig. 8, rises with an increase of pressure or temperature to values far exceeding those obtained with cold compacted and subsequently sintered powders. The density of cast oxygen-free high conductivity copper is reached by hot compressed compacts, when a pressure of 50 tons per sq. in. is applied at 400 deg. C.

In spite of their incompletely developed polygonal structure (shown in Fig. 7) the specimens of coarse powders compacted at high pressures at 400 deg. C. could be rolled and drawn into wire without any intermediate annealing (as could the other specimens, which had better developed structures). The lack of porosity and the large extent of recrystallization of the larger particles may explain this remarkable malleability and ductility of a material that showed only incipient grain growth. Sintered compacts, on the other hand, had to be subjected to a double compression and sintering operation and to several annealings during rolling in order to secure reduction to wires. It seems likely that hot compressed compacts manufactured at even higher temperatures, such as 500 deg. or 600 deg. C., would yield a material of excellent malleability and ductility, and might be comparable with "gross" copper in this respect.

Hot compressed compacts also showed a marked improvement in hardness in comparison with sintered copper. At compression temperatures around 300 deg. C., the values of hardness obtained for moderate pressures (50 tons per sq. in.) are close to those of cold compressed or repressed material to which extremely high pressures (190 tons per sq. in.) were applied. Although the extremely high hardness values of Trzebiatowski's research could not quite be reached, probably because he used a powder much finer than any used in this investigation, values of 130 Brinell as obtained in this work, are still of remarkable magnitude for copper.

Compressive strength tests (Figs. 8 and 9) on hot compressed compacts revealed a definite agreement with observations made during the rolling tests. Evidently high malleability and compressibility are both closely connected with the recrystallization and incipient grain growth of the particles, as established in compacts compressed at temperatures above 300 deg. C. In the case of the compressive strength tests, values were reached that were scarcely met by any cold-compacted and sintered material.

Practical Choice of Processing Methods

The question of the desired degree of density is of great importance for the selection of the proper method of processing compacted copper. In cold compressed and sintered compacts, the porosity can be controlled within a certain limit down to a minimum of a few per cent. If the amount of porosity that can be tolerated is below that limit a hot compression process is necessary, provided the outlines of the desired finished compacted specimens are not too complicated. Otherwise, the problem cannot be handled very well by the present powder metallurgical processing methods.

Shrinkage effects during sintering can be counteracted by the use of a powder of moderate particle size, and by reducing the temperature and period of heat-treatment to a minimum.

If high electrical conductivity is desired, highest densities of the compacts and greatest care in purifying the powder are necessary, as cavities and impurities are most detrimental to the electrical conductivity of the copper compacts.

If great hardness is desired, the compacts must be produced from fine powders, either by hot compression or by sintering and a subsequent repressing at high pressures.

High tensile, compressive, or fatigue strength require fine initial powders, a duplex cold-compressing and vacuum-sintering procedure, with high compacting pressures, temperatures above 720 deg. C. and periods of heat treatment of more than 12 hrs. On the other hand, hot compressing above 400 deg. C. at high pressures would serve the same purpose.

If high malleability and ductility are required, dense compacts can be developed from coarser, but very pure powders. A double-compressing and vacuum-sintering procedure is most advantageous, but can be replaced by a hot compressing process that employs high pressures, and temperatures between 400 deg. C. and 600 deg. C. The advantages of the hot compressing technique are many, and merit wider consideration in powder metallurgy generally.

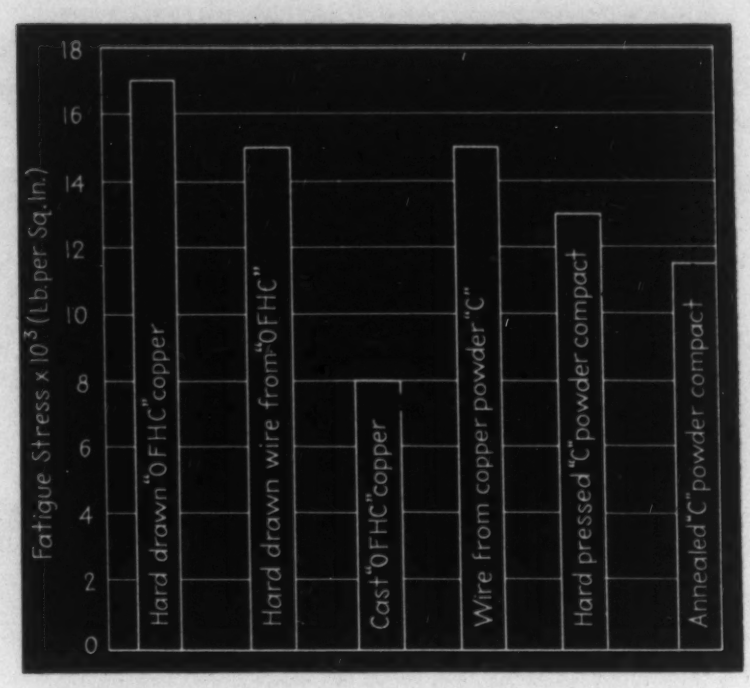


Fig. 11. Fatigue properties of various products made from electrolytic copper powder C.

letter

TO THE EDITOR

More About "Wanted—Words"

To the Editor: The editorial in the June issue of METALS AND ALLOYS "Wanted—Words" has been read with considerable interest.

In working with precious metals' alloys we have encountered all of the difficulties which you discuss with reference to elastic limit, proportional limit, yield point, etc. Any standardization regarding tests and nomenclature would be especially welcome. As you state in your editorial, "Many of the metals do not show any yield point," and the gold alloys are notorious in this respect.

The Bureau of Standards has selected a method for the American Dental Association specification which measures the strain between two limiting stresses, giving somewhat of a combination of modulus of elasticity and "proportional limit." This test has the advantage that it can be made rapidly and with considerable accuracy. It is described as follows:

"Yield point:

* * *

B. An initial load calculated to produce a stress of 5,000 lbs. per sq. in. shall be applied to the sample and the strain gauge read. The load shall then be increased to the minimum values for the yield point (Type B, 22,000 lbs. per sq. in.; Type C, 27,000 lbs. per sq. in), and a second reading taken. The maximum strain permitted between the limits specified is: Type B, 0.0017 in. per in.; Type C, 0.002 in. per in."

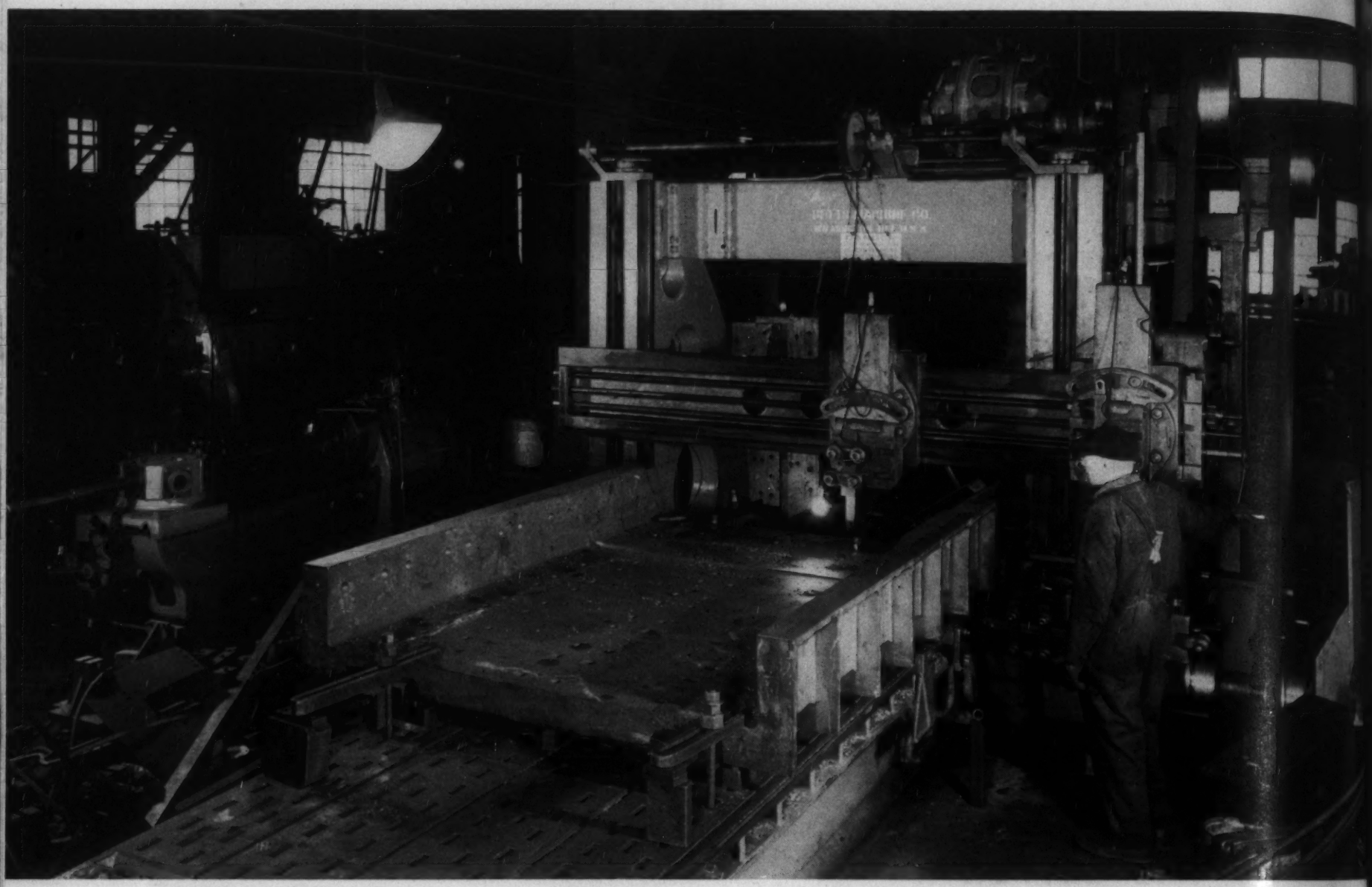
It would be advantageous to have in the precious metal field methods of testing accompanied by adequate nomenclature, so that we could discuss these values intelligently among ourselves and with our customers.

I have even gone to the trouble of substituting a bending test on the Tinius Olsen stiffness tester to simplify the testing method, although the nomenclature in bending and stiffness tests is far from adequate.

I hope that your editorial will bring sufficient response to warrant standardizing this nomenclature.

J. S. SHELL

Thomas J. Dee & Co., 1900 W. Kinzie St., Chicago.



Machining a large lock and dam casting carrying a specification of 60,000 lbs. minimum tensile strength. This specification is readily met in a cupola cast iron by the introduction of copper and molybdenum to the ladle. (Courtesy Advance Foundry Co., Dayton, Ohio)

Medium-Carbon Irons

The mechanical properties of the medium-carbon series (3.07-3.20 per cent C) are summarized in Table II. The properties of the 4, 2, 1.2 and 0.875-in. dia. bars are plotted for the 1.44 to 1.59 per cent Si and the 1.93 to 2.05 per cent Si grades in Fig. 2.

The general level of properties in this series is higher than that of the high-carbon series owing to the difference in carbon content; yet the trend for the effect of copper is the same for both series. This is indicated by the slope of the curves in Figs. 1 and 2.

Low-Carbon Irons

The mechanical properties of these irons of the low-carbon series (2.86-2.98 per cent C) are shown in Table III. The mechanical properties of the 1.54 to 1.58 per cent Si and the 2.01 to 2.06 per cent Si groups are plotted in Fig. 3.

The tensile strength and Brinell hardness appear to increase with increasing copper contents while the deflection and transverse strength decrease with an increase in copper. Copper had little effect on the properties of the high-silicon irons (2.48-2.52 per cent Si) of this group, except to increase the Brinell hardness.

Alloy Cast Irons

The alloy irons studied contained from 3.12 to 3.23 per cent C and from 1.48 to 1.74 per cent Si. These composition ranges are the same as for one

Containing Copper PART 2, CONCLUDED FROM JULY

of the groups of the medium-carbon series shown in Table II. The mechanical properties of these alloy irons are tabulated in Table IV. Most of the irons in this series have unusually good properties so that there is little choice among them from the standpoint of tensile strength.

The small spread in properties among irons of this group points to the fact that by judicious choice of the proper elements some relatively simple combination can be used to obtain tensile strengths that are on a par with those secured by the more complex and expensive combinations quite frequently advocated. Copper fits into the simple combinations very nicely. Table II shows that in the medium-carbon irons, the use of copper alone in amounts above 1 per cent brings the irons into the A.S.T.M. Class

TABLE II. The Composition and Mechanical Properties of the Medium-Carbon Cast Irons of Varying Silicon and Copper Contents

Battelle Heat No.	Bar No.	Composition, Per Cent	Cast Bar Size, In.	Tensile Strength, Lb./In.²	Transverse Strength, Lb.	Transverse Deflection, In.	Modulus of Rupture, Lb./In.²	Resilience, Ft.-Lb.	Brinell Hardness	Impact, Ft.-Lb.
4761	22	C -3.16	0.875	.....	.....	....	.....	...	...	10
		Si -0.71	1.2	.....	2,450	0.124	65,000	13	...	22
		Cu-0.00	2.0	43,500	10,900	0.393	83,000	231	207	..
			4.0	39,500	.....	....	.....	...	214	..
4761	23	C -3.12	0.875	.....	.....	....	.....	...	...	10
		Si -0.71	1.2	46,000	3,650	0.302	97,000	55	238	38
		Cu-0.91	2.0	47,000	11,800	0.340	90,000	212	221	..
			4.0	44,000	.....	....	.....	...	232	..
4761	24	C -3.05	0.875	51,000	1,750	0.095	79,000	7	280	9
		Si -0.68	1.2	58,500	3,450	0.245	91,000	38	257	41
		Cu-1.90	2.0	55,000	11,000	0.274	84,000	139	244	..
			4.0	48,000	.....	....	.....	...	255	..
4762	25	C -3.07	0.875	.....	.....	....	.....	...	...	12
		Si -1.14	1.2	51,000	3,250	0.342	86,000	60	219	55
		Cu-0.00	2.0	46,500	11,800	0.373	90,000	231	217	..
			4.0	44,000	.....	....	.....	...	228	..
4762	26	C -3.08	0.875	.....	.....	....	.....	...	...	..
		Si -1.11	1.2	51,000	3,250	0.256	86,000	40	238	41
		Cu-1.01	2.0	50,000	11,600	0.300	89,000	168	240	..
			4.0	46,000	.....	....	.....	...	241	..
4762	27	C -3.07	0.875	61,000	2,150	0.156	97,000	15	261	15
		Si -1.12	1.2	55,000	3,350	0.250	89,000	39	244	42
		Cu-1.41	2.0	53,000	11,600	0.312	89,000	166	248	..
			4.0	46,000	.....	....	.....	...	252	..
4763	28	C -3.13	0.875	62,500	2,300	0.173	105,000	18	267	18
		Si -1.15	1.2	52,000	3,750	0.294	100,000	52	251	45
		Cu-1.92	2.0	51,500	11,900	0.327	91,000	191	235	..
			4.0	50,000	.....	....	.....	...	241	..
4763	29	C -3.12	0.875	52,500	2,300	0.176	105,000	18	275	14
		Si -1.13	1.2	53,000	3,700	0.280	99,000	48	261	42
		Cu-2.82	2.0	.....	12,100	0.292	92,000	165	245	..
			4.0	50,500	.....	....	.....	...	259	..
4764	30	C -3.16	0.875	52,000	2,000	0.188	91,000	18	230	15
		Si -1.54	1.2	48,500	3,250	0.379	86,000	67	213	45
		Cu-0.00	2.0	44,000	10,800	0.405	83,000	237	205	..
			4.0	42,000	.....	....	.....	...	198	..
4764	31	C -3.20	0.875	52,500	2,050	0.176	94,000	17	237	15
		Si -1.50	1.2	47,500	3,350	0.378	89,000	67	218	47
		Cu-0.53	2.0	45,500	11,400	0.345	87,000	202	210	..
			4.0	43,500	.....	....	.....	...	206	..

(Continued on Next Page)

by T. E. BARLOW

Metallurgical Engineer,
Copper, Iron and Steel Development Ass'n.,
Cleveland

TABLE II, *(Continued from page 159)*

Battelle Heat No.	Bar No.	Composition, Per Cent	Cast Bar Size, In.	Tensile Strength, Lb./In.²	Transverse Strength, Lb.	Transverse Deflection, In.	Modulus of Rupture, Lb./In.²	Resilience, Ft.-Lb.	Brinell Hardness	Impact, Ft.-Lb.
4765	32	C -3.18	0.875	54,500	.....	....	.....	...	247	17
		Si -1.59	1.2	50,000	3,250	0.300	87,000	48	228	43
		Cu-0.99	2.0	50,000	11,900	0.305	91,000	179	230	..
			4.0	45,500	.....	....	.....	...	238	..
4765	33	C -3.15	0.875	54,000	2,150	0.178	98,000	18	255	17
		Si -1.58	1.2	53,000	3,300	0.300	88,000	49	233	41
		Cu-1.45	2.0	48,500	11,500	0.311	88,000	172	238	..
			4.0	47,500	.....	....	.....	...	241	..
4766	34	C -3.18	0.875	58,500	2,300	0.189	105,000	20	265	16
		Si -1.49	1.2	54,500	3,600	0.312	95,000	54	242	43
		Cu-1.98	2.0	48,000	11,200	0.328	86,000	185	234	..
			4.0	48,500	.....	....	.....	...	239	..
4766	35	C -3.16	0.875	57,500	2,200	0.171	100,000	17	273	15
		Si -1.44	1.2	56,000	3,550	0.291	94,000	48	253	44
		Cu-3.10	2.0	55,000	11,500	0.302	88,000	164	243	..
			4.0	51,000	.....	....	.....	...	245	..
4767	36	C -3.15	0.875	50,500	2,050	0.210	93,000	22	225	17
		Si -1.93	1.2	46,000	3,250	0.356	86,000	61	208	40
		Cu-0.00	2.0	40,500	10,700	0.369	82,000	208	205	..
			4.0	44,000	.....	....	.....	...	205	..
4767	37	C -3.16	0.875	48,500	2,100	0.199	96,000	21	232	15
		Si -1.93	1.2	47,000	3,350	0.353	89,000	62	214	43
		Cu-0.54	2.0	43,500	10,700	0.346	81,000	185	214	..
			4.0	43,500	.....	....	.....	...	207	..
4767	38	C -3.16	0.875	51,000	2,100	0.210	97,000	23	239	17
		Si -1.96	1.2	48,000	3,350	0.319	89,000	51	222	38
		Cu-0.96	2.0	44,000	10,900	0.349	83,000	192	224	..
			4.0	45,500	.....	....	.....	...	216	..
4768	39	C -3.14	0.875	55,000	2,100	0.207	96,000	21	251	15
		Si -2.04	1.2	51,000	3,400	0.309	89,000	52	232	39
		Cu-1.44	2.0	43,000	11,100	0.294	85,000	153	235	..
			4.0	44,500	.....	....	.....	...	227	..
4768	40	C -3.19	0.875	54,000	2,000	0.180	92,000	17	253	17
		Si -2.05	1.2	45,000	3,350	0.307	88,000	50	239	42
		Cu-2.00	2.0	45,000	10,700	0.280	81,000	138	240	..
			4.0	45,500	.....	....	.....	...	228	..
4769	41	C -3.12	0.875	43,000	1,800	0.195	83,000	17	211	15
		Si -2.61	1.2	41,000	3,000	0.345	80,000	53	201	39
		Cu-0.00	2.0	37,000	9,500	0.344	73,000	169	203	..
			4.0	41,000	.....	....	.....	...	211	..
4769	42	C -3.17	0.875	49,000	2,000	0.188	92,000	18	229	16
		Si -2.57	1.2	42,500	3,000	0.319	80,000	48	214	37
		Cu-0.50	2.0	38,000	9,500	0.307	72,000	145	207	..
			4.0	43,000	.....	....	.....	...	214	..
4769	43	C -3.14	0.875	44,000	2,050	0.191	94,000	19	235	15
		Si -2.56	1.2	42,500	3,300	0.344	88,000	57	223	35
		Cu-0.96	2.0	39,000	9,700	0.302	74,000	139	216	..
			4.0	42,500	.....	....	.....	...	216	..

50 grade. Very effective simple combinations of alloying elements are copper-molybdenum, copper-chromium, and copper-vanadium. The results obtained with these combinations are striking.

Effect of Copper on Chilling Properties

The broad range of silicon contents covered made it possible to observe the influence of copper on chill formation. Photographs of step bar and chill test castings which have been sectioned, etched to show the chill and mottling, and surveyed for hardness are shown in Figs. 4, 5 and 6. The step bar casting was 1.5 in. wide. It was split down the center with a rubber-bonded wheel and given a light etch with a cold 10% solution of ammonium persulphate to develop the contrast between the gray, mottled and chilled areas. The chill test casting was ½ in. thick by 3 x 3 in. square, with one of the ½ x 3-in. faces cast against a steel chill. This casting was also split through the center at right angles to the chilled face and etched. Brinell readings were taken on the 1 and ½-in. sections of the step bar, while Vickers readings were taken on the ¼ and ⅛-in. sections. In the range of hardness concerned the Brinell and Vickers readings are for practical purposes interchangeable.

Photographs of a few irons of the high-carbon series are shown in Fig. 4. It is evident that copper is a mild chill reducer and that it raises the hardness of the gray areas. Because of their lower carbon contents, the irons of the medium-carbon series

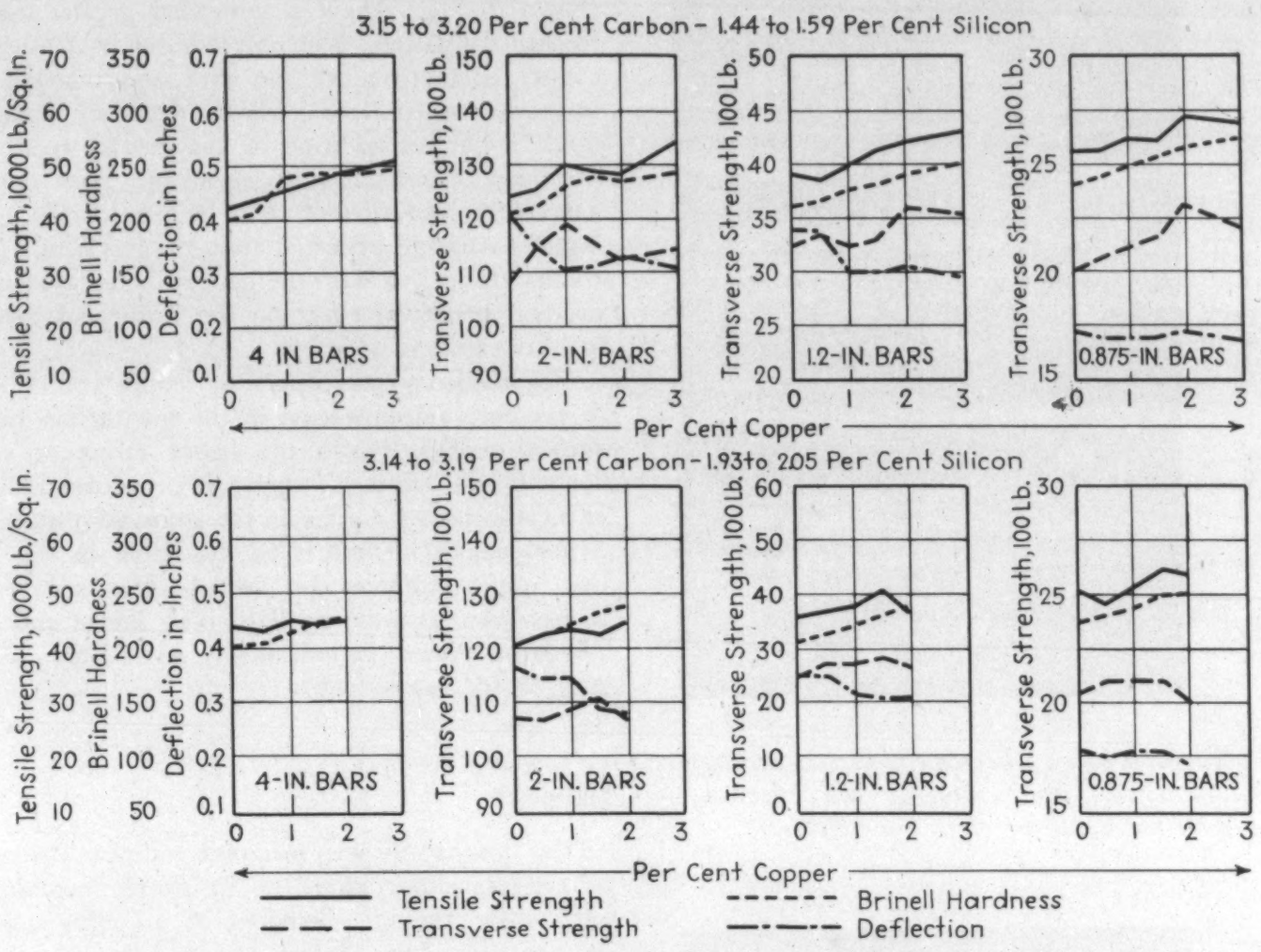
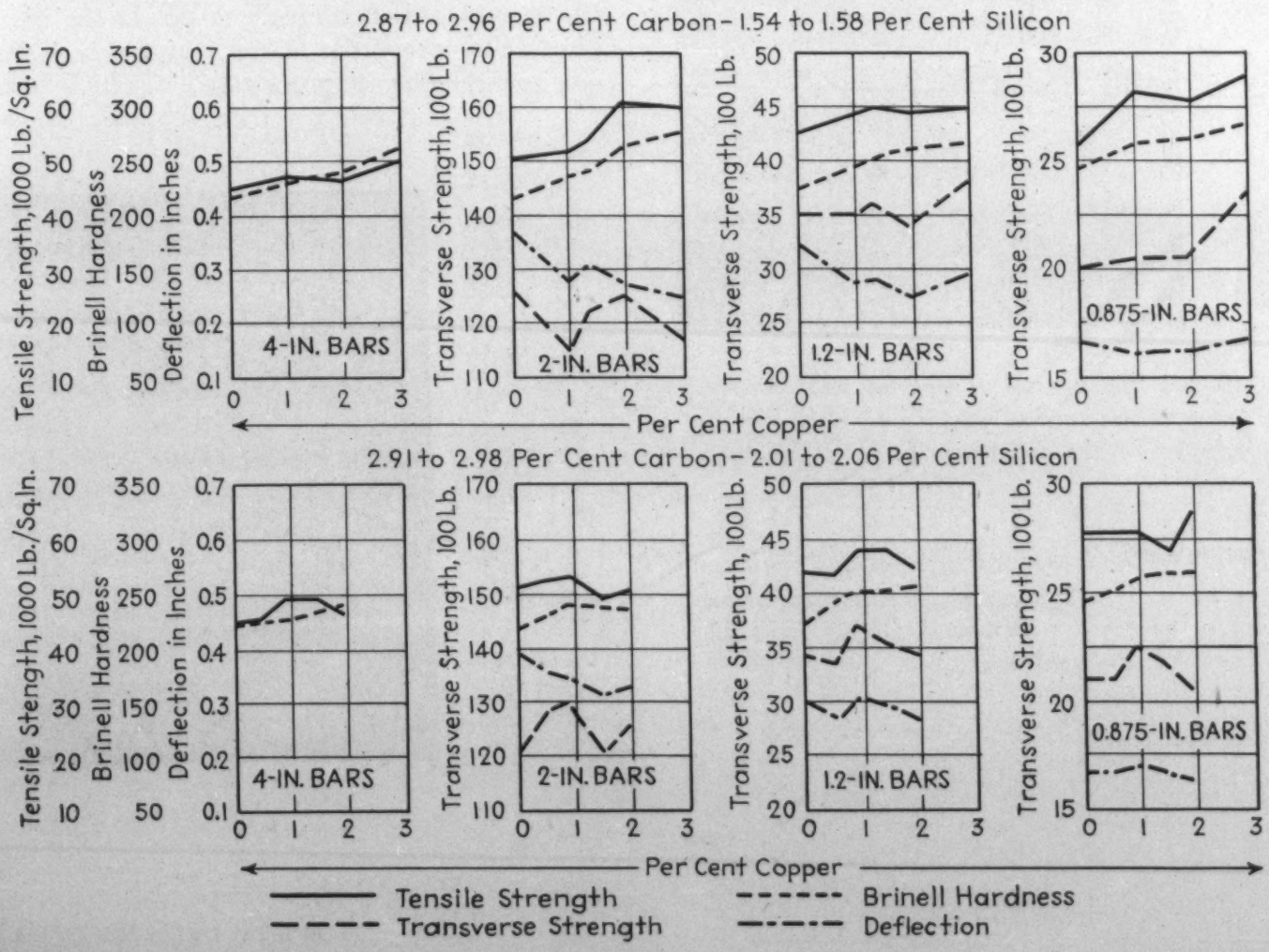


Fig. 2. The effect of copper on the properties of medium-carbon cast iron.

Fig. 3. The effect of copper on the properties of low-carbon cast iron.



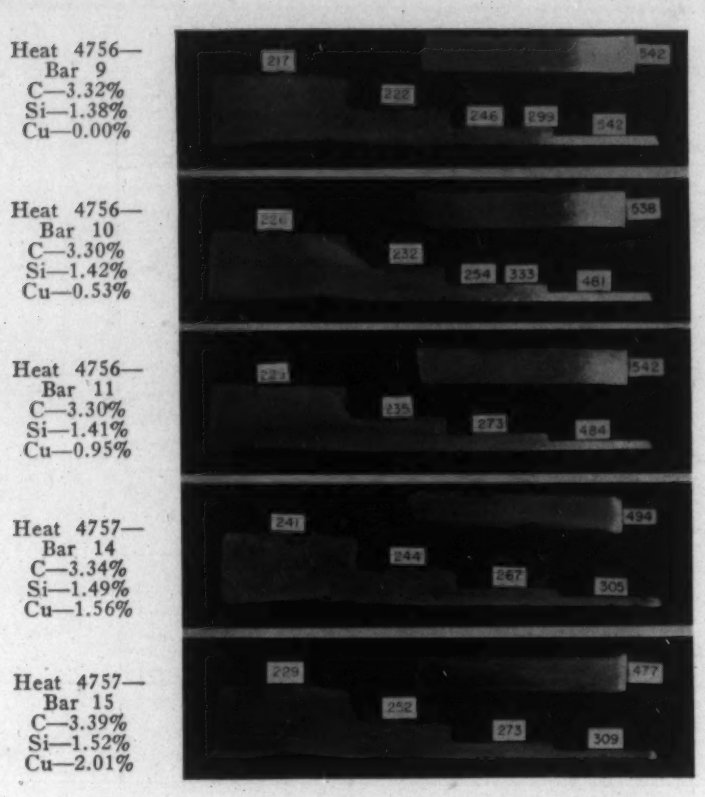


Fig. 4. Photograph of step bar and chill test castings for high-carbon cast irons showing the effect of copper on the depth of chill and hardness.

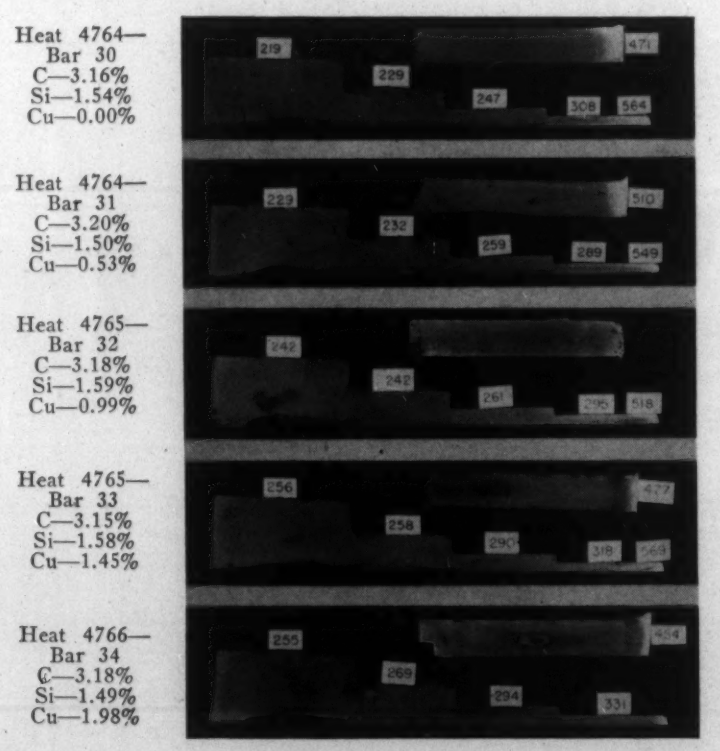


Fig. 5. (Above) Photograph of step bar and chill test castings for medium-carbon cast irons showing the effect of copper on the depth of chill and hardness.

Fig. 6. (Right) Photograph of step bar and chill test castings of the low-carbon series of cast irons showing the effect of copper on the depth of chill and hardness.

shown in Fig. 5 have a somewhat greater tendency to chill formation. Not only does an increase in the copper content reduce the chill and mottled areas in the low-silicon irons, which are highly susceptible to chill, but the addition of copper also reduces the shrinkage. Reduction of shrinkage goes hand in hand with reduction of chill because of the greater liquid shrinkage of white than of gray iron. These results are in line with the general belief that copper exerts a beneficial effect on the density of cast iron in heavy sections.

The tendency for copper to reduce the chill and to promote graphitization in the low-carbon irons is shown in Fig. 6. In the lower range of silicon contents, the effect of copper is pronounced, but its effect diminishes rapidly in the irons with more than 2 per cent Si. There is no indication in this work that copper promotes chill in the higher-silicon irons as has been reported by Eastwood, Bousu and Eddy (*Bulletin,* Amer. Foundrymen's Association, Vol. 7, Aug. 1936, pages 50-97).

Summary

The results of this program indicate the utility of copper, either alone or in simple combination with other alloying elements, as an alloy addition to cast irons. In general, the addition of 1 to 2 per cent copper to the usual grades of engineering cast irons results in an increase in the tensile strength, the transverse strength and the Brinell hardness. The tendency of copper to lower the values for transverse deflection increases as the carbon content of the iron is lowered. This is not pronounced in the irons of the high- and medium-carbon series, containing about 3.40 and 3.10 per cent C. The desirability of a balanced composition with due regard to the copper, silicon and carbon contents to obtain the best combination of properties at the lowest cost is brought out in the tables of properties.

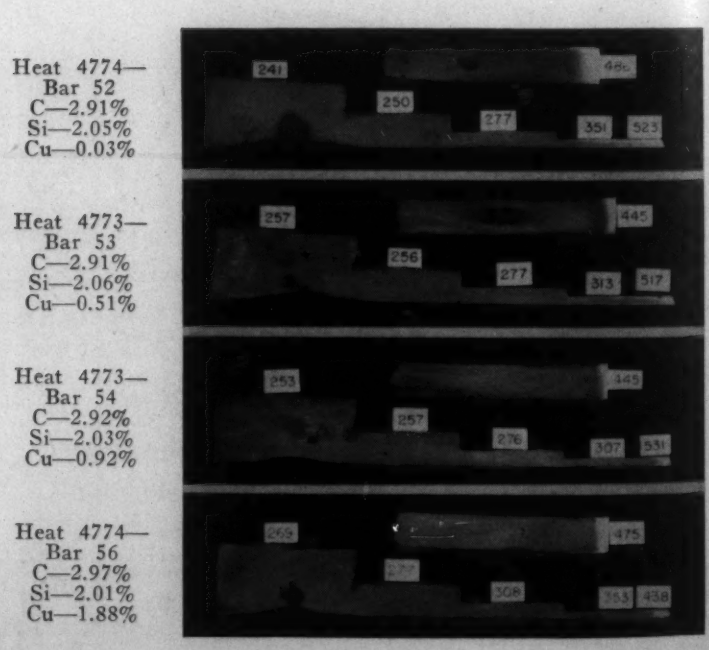


TABLE III. The Composition and Mechanical Properties of the Low-Carbon Cast Irons of Varying Silicon and Copper Contents

Battelle Heat No.	Bar No.	Composition, Per Cent	Cast Bar Size, In.	Tensile Strength, Lb./In.²	Transverse Strength, Lb.	Transverse Deflection, In.	Modulus of Rupture, Lb./In.²	Resilience, Ft.-Lb.	Brinell Hardness	Impact, Ft.-Lb.
4770	44	C -2.94	0.875	.....	1,950	0.131	89,000	12	...	13
		Si -1.11	1.2	53,500	3,400	0.337	90,000	62	228	52
		Cu-0.00	2.0	49,000	11,000	0.321	84,000	186	222	..
			4.0	38,000	.....	....	.....	...	217	..
4770	45	C -2.95	0.875	60,000	1,950	0.123	90,000	11	268	13
		Si -1.09	1.2	55,500	3,450	0.258	91,000	44	251	40
		Cu-0.95	2.0	55,000	11,400	0.269	87,000	150	238	..
			4.0	42,500	.....	....	.....	...	236	..
4770	46	C -2.87	0.875	60,500	.....	....	.....	...	282	13
		Si -1.11	1.2	59,000	3,250	0.217	87,000	32	268	35
		Cu-1.99	2.0	52,000	11,500	0.266	88,000	145	250	..
			4.0	45,000	.....	....	.....	...	247	..
4771	47	C -2.90	0.875	53,000	2,000	0.165	92,000	16	243	15
		Si -1.57	1.2	55,500	3,500	0.347	93,000	65	225	47
		Cu-0.00	2.0	51,000	12,700	0.373	97,000	242	217	..
			4.0	45,000	.....	....	.....	...	217	..
4771	48	C -2.89	0.875	63,000	2,050	0.145	92,000	13	267	13
		Si -1.57	1.2	58,500	3,500	0.278	93,000	48	246	40
		Cu-1.01	2.0	52,000	11,500	0.291	88,000	165	239	..
			4.0	47,000	.....	....	.....	...	230	..
4771	49	C -2.87	0.875	62,500	2,050	0.148	94,000	14	268	14
		Si -1.58	1.2	60,000	3,600	0.281	96,000	48	253	39
		Cu-1.34	2.0	54,000	12,200	0.313	94,000	189	240	..
			4.0	47,000	.....	....	.....	...	232	..
4772	50	C -2.91	0.875	61,500	2,050	0.150	94,000	14	271	15
		Si -1.54	1.2	59,500	3,400	0.252	91,000	39	261	37
		Cu-1.95	2.0	61,000	12,600	0.276	96,000	157	265	..
			4.0	46,500	.....	....	.....	...	238	..
4772	51	C -2.96	0.875	66,000	2,350	0.176	106,000	18	285	16
		Si -1.56	1.2	60,000	3,750	0.293	100,000	51	266	41
		Cu-3.00	2.0	60,000	11,700	0.256	89,000	132	277	..
			4.0	50,000	.....	....	.....	...	262	..
4773	52	C -2.91	0.875	61,000	2,100	0.168	95,000	17	243	17
		Si -2.05	1.2	54,000	3,400	0.299	91,000	50	233	45
		Cu-0.03	2.0	51,000	12,100	0.390	92,000	249	218	..
			4.0	45,000	.....	....	.....	...	223	..
4773	53	C -2.91	0.875	61,000	2,100	0.166	95,000	17	251	14
		Si -2.06	1.2	53,500	3,350	0.269	89,000	44	241	37
		Cu-0.51	2.0	52,500	12,800	0.358	98,000	232	228	..
			4.0	45,500	.....	....	.....	...	226	..
4773	54	C -2.92	0.875	61,000	2,250	0.180	102,000	19	264	19
		Si -2.03	1.2	58,000	3,700	0.308	98,000	55	251	44
		Cu-0.92	2.0	53,000	13,000	0.346	99,000	221	240	..
			4.0	49,000	.....	....	.....	...	227	..
4774	55	C -2.98	0.875	57,500	2,150	0.165	97,000	16	268	16
		Si -2.06	1.2	58,000	3,500	0.286	93,000	47	252	44
		Cu-1.50	2.0	49,000	12,100	0.313	92,000	176	238	..
			4.0	49,000	.....	....	.....	...	235	..
4774	56	C -2.97	0.875	65,000	2,050	0.152	92,000	14	269	14
		Si -2.01	1.2	54,500	3,450	0.271	91,000	43	256	43
		Cu-1.88	2.0	50,000	12,500	0.326	95,000	191	235	..
			4.0	46,500	.....	....	.....	...	240	..
4775	57	C -2.89	0.875	57,000	2,100	0.189	96,000	19	243	16
		Si -2.52	1.2	55,500	3,450	0.334	92,000	59	230	41
		Cu-0.03	2.0	45,000	13,200	0.372	101,000	241	217	..
			4.0	46,000	.....	....	.....	...	226	..
4775	58	C -2.28	0.875	60,500	.....	....	.....	...	234	..
		Si -2.51	1.2	56,500	3,450	0.298	92,000	49	238	36
		Cu-0.52	2.0	46,500	.....	....	.....	...	225	..
			4.0	48,000	.....	....	.....	...	235	..
4775	59	C -2.86	0.875	59,500	2,150	0.165	98,000	16	267	14
		Si -2.48	1.2	57,500	3,450	0.280	92,000	45	249	37
		Cu-0.89	2.0	51,000	12,000	0.329	92,000	187	240	..
			4.0	47,500	.....	....	.....	...	231	..

Table Four on Next Two Pages

TABLE IV. The Composition and Mechanical Properties of the Alloy Cast Irons

Battelle Heat No.	Bar No.	Composition, Per Cent C	Si	Alloys	Bar Size, In.	Tensile Strength, Lb./In.²	Transverse Strength, Lb.	Transverse Deflection, In.	Modulus of Rupture, Lb./In.²	Resilience, Ft.-Lb.	Brinell Hardness	Impact, Ft.-Lb.
4862	66	3.12	1.55	Cu-0.00	0.875	52,500	2,100	0.191	97,000	20	238	15
				Ni-1.00	1.2	47,500	3,150	0.280	83,000	43	223	39
					2.0	42,000*	10,700	0.323	82,000	172	217	..
					4.0	44,000	.....	....	.....	...	229	..
4862	67	3.14	1.52	Cu-0.51	0.875	60,000	2,100	0.169	96,000	17	252	15
				Ni-1.02	1.2	55,000	3,350	0.299	90,000	49	234	39
					2.0	48,000	10,900	0.290	83,000	153	222	..
					4.0	47,500	.....	....	.....	...	232	..
4862	68	3.13	1.50	Cu-0.97	0.875	57,500	2,100	0.162	95,000	16	256	15
				Ni-0.98	1.2	56,500	3,350	0.268	89,000	42	251	36
					2.0	46,000	10,600	0.270	81,000	135	234	..
					4.0	45,500	.....	....	.....	...	234	..
4863	69	3.15	1.51	Cu-0.93	0.875	57,500	2,050	0.166	93,000	16	252	14
				Ni-0.51	1.2	53,000	3,300	0.296	87,000	47	232	40
					2.0	47,000*	10,800	0.265	82,000	132	241	..
					4.0	46,000	.....	....	.....	...	224	..
4863	70	3.16	1.63	Cu-0.03	0.875	56,500	1,950	0.175	99,000	16	243	17
				Ni-2.01	1.2	49,000	3,150	0.286	84,000	43	231	36
					2.0	46,000	10,000	0.262	76,000	122	235	..
					4.0	45,000	.....	....	.....	...	217	..
4864	71	3.20	1.48	Cu-0.00	0.875	56,000	1,800	0.120	82,000	10	245	15
				Cr-0.51	1.2	53,000	3,350	0.286	89,000	47	237	37
					2.0	50,000	11,600	0.314	89,000	182	229	..
					4.0	43,000	.....	....	.....	...	228	..
4864	72	3.15	1.60	Cu-0.00	0.875	61,000	2,050	0.164	94,000	16	254	13
				Ni-1.36	1.2	56,000	3,350	0.272	89,000	43	247	34
				Cr-0.53	2.0	55,000	9,700	0.227	74,000	99	251	..
					4.0	47,000	.....	....	.....	...	241	..
4865	75	3.23	1.52	Cu-1.56	0.875	59,000	2,100	0.160	95,000	15	272	13
				Cr-0.52	1.2	57,500	3,300	0.254	88,000	38	262	41
					2.0	47,000*	10,800	0.268	83,000	134	242	..
					4.0	46,000	.....	....	.....	...	256	..
4865	76	3.21	1.63	Cu-0.74	0.875	62,000	2,000	0.147	91,000	13	270	13
				Ni-0.75	1.2	54,500	3,200	0.257	84,000	37	253	36
				Cr-0.52	2.0	46,500*	9,900	0.247	75,000	111	241	..
					4.0	47,000	.....	....	.....	...	253	..
4866	77	3.22	1.51	Cu-0.00	0.875	63,000	2,150	0.211	97,000	23	252	23
				Mo-0.51	1.2	57,500	3,550	0.355	95,000	66	233	56
					2.0	47,000	11,800	0.418	90,000	269	220	..
					4.0	46,000	.....	....	.....	...	217	..
4866	78	3.13	1.50	Cu-1.54	0.875	59,000	2,400	0.190	110,000	21	275	19
				Mo-0.50	1.2	61,000	3,850	0.312	102,000	57	263	48
					2.0	49,000*	12,400	0.318	94,000	191	255	..
					4.0	52,000	.....	....	.....	...	248	..
4866	79	3.16	1.52	Cu-1.48	0.875	68,000	2,450	0.184	111,000	21	285	21
				Cr-0.35	1.2	66,000	3,900	0.310	103,000	58	271	52
				Mo-0.50	2.0	57,000	12,900	0.299	99,000	182	259	..
					4.0	53,500	.....	....	.....	...	255	..
4867	80	3.14	1.56	Cu-0.00	0.875	66,000	2,350	0.194	107,000	21	274	19
				Ni-1.50	1.2	59,500	3,650	0.338	97,000	61	257	53
				Mo-0.47	2.0	51,000*	12,000	0.314	92,000	179	243	..
					4.0	49,000	.....	....	.....	...	255	..
4867	81	3.21	1.68	Cu-0.00	0.875	68,500	2,350	0.180	107,000	20	283	16
				Ni-1.48	1.2	62,500	3,550	0.264	95,000	43	271	43
				Cr-0.51	2.0	51,500	12,100	0.291	92,000	165	258	..
				Mo-0.47	4.0	56,000	.....	....	.....	...	268	..
4867	82	3.21	1.74	Cu-0.71	0.875	70,500	2,150	0.163	98,000	16	301	15
				Ni-0.75	1.2	63,500	3,500	0.256	93,000	40	281	45
				Cr-0.53	2.0	52,000	10,700	0.246	81,000	120	264	..
				Mo-0.47	4.0	56,000	.....	....	.....	...	282	..
4868	83	3.23	1.56	Cu-0.00	0.875	57,000	2,050	0.208	93,000	22	237	20
				V -0.09	1.2	49,500	3,250	0.343	86,000	58	221	48
					2.0	44,500	10,700	0.309	82,000	165	227	..
					4.0	43,000	.....	....	.....	...	215	..
4868	84	3.19	1.54	Cu-0.82	0.875	59,000	2,050	0.168	93,000	16	250	16
				V -0.10	1.2	54,000	3,350	0.287	89,000	47	238	40
					2.0	50,000	11,100	0.284	85,000	151	230	..
					4.0	45,500	.....	....	.....	...	229	..

(Continued on Next Page)

Battelle Heat No.	Bar No.	Composition, Per Cent C	Si	Alloys	Bar Size, In.	Tensile Strength, Lb./In.²	Transverse Strength, Lb.	Transverse Deflection, In.	Modulus of Rupture, Lb./In.²	Resilience, Ft.-Lb.	Brinell Hardness	Impact, Ft.-Lb.
4868	85	3.18	1.59	Cu-0.00	0.875	58,500	2,000	0.185	91,000	18	244	16
				Ni-0.75	1.2	52,000	3,350	0.321	89,000	55	229	40
				V -0.10	2.0	49,000*	10,600	0.296	81,000	152	227	..
					4.0	43,500	.....	....	.....	...	217	..
4890	86	3.21	1.49	Cu-0.74	0.875	58,000	.....	....	.....	...	253	15
				V -0.10	1.2	52,500	3,300	0.293	87,000	47	233	41
					2.0	43,500	.....	....	.....	...	223	..
					4.0	42,000	.....	....	.....	...	229	..
4890	87	3.20	1.50	Cu-0.76	0.875	65,500	2,250	0.184	102,000	19	277	17
				Mo-0.48	1.2	59,500	3,550	0.290	95,000	49	256	46
				V -0.10	2.0	47,500	11,900	0.328	91,000	191	234	..
					4.0	48,500	.....	....	.....	...	234	..
4954	88	3.16	1.48	Cu-1.50	0.875	56,500	1,850	0.137	83,000	11	267	16
				V -0.09	1.2	53,000	3,200	0.261	85,000	39	249	37
					2.0	47,000*	11,300	0.280	86,000	147	236	..
					4.0	42,500	.....	....	.....	...	231	..
4954	89	3.15	1.53	Cu-0.00	0.875	59,000	1,850	0.152	85,000	13	256	17
				Ni-1.53	1.2	52,500	3,100	0.272	83,000	40	235	36
				V -0.09	2.0	42,500	9,800	0.278	75,000	131	228	..
					4.0	43,000	.....	....	.....	...	218	..
4955	90	3.18	1.54	Cu-0.74	0.875	57,000	2,050	0.178	94,000	17	255	19
				Ni-0.76	1.2	52,500	3,150	0.286	84,000	43	240	41
				V -0.09	2.0	43,500	10,100	0.294	77,000	145	228	..
					4.0	45,500	.....	....	.....	...	234	..
4955	91	3.14	1.56	Cu-0.74	0.875	68,000	2,300	0.177	104,000	19	289	18
				Ni-0.75	1.2	56,500	3,700	0.292	98,000	50	268	47
				Mo-0.49	2.0	52,500	11,800	0.289	90,000	162	252	..
				V -0.08	4.0	52,500	.....	....	.....	...	239	..

* These values are questionable, due to possible flaws in the single specimen tested.

Chuckles

Some Heat-Treating Furnace!

The following statement on a postal card has been called to our attention by the president of a prominent metallurgical laboratory in Philadelphia, with a request for possible information concerning the "mysterious process" described. We reproduce the statement:

A new continuous
ANNEALING—PROCESS for METALS

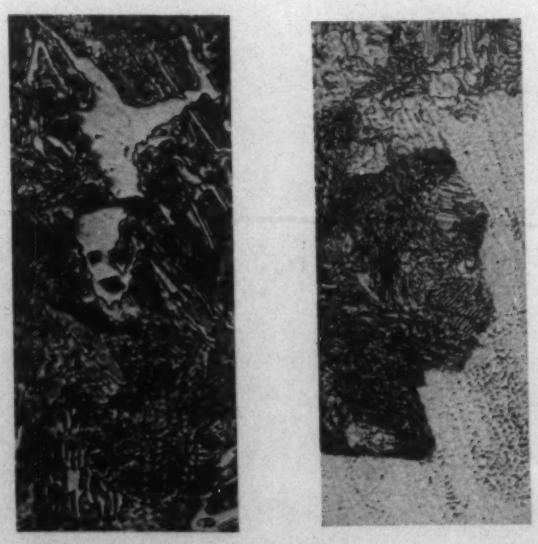
of very lengthy and rigid form up to 80 ft. and more which requires no PICKLING afterwards, WHICH needs no protective gas against oxidizing activity of the air, which has not been evacuated, but a phenomena happens and hinders the physical attack on the surface-structure of the metals while treating, has been patented in a foreign country.

High economical, process velocity 3 to 15 ft. per minute by a pipe of 18/20 diam., multiple charge possible; all metal articles, railroad rails, billets, bars, rods, wires, slabs, shafts, axles, wheels, tubes, pipes, structural members of great lengths, forged material, rolled material, in iron, cast iron, wrought iron, steel, copper, brass, their alloys etc. Complete translation for a check of 11,75. ReII/27 Very truly—

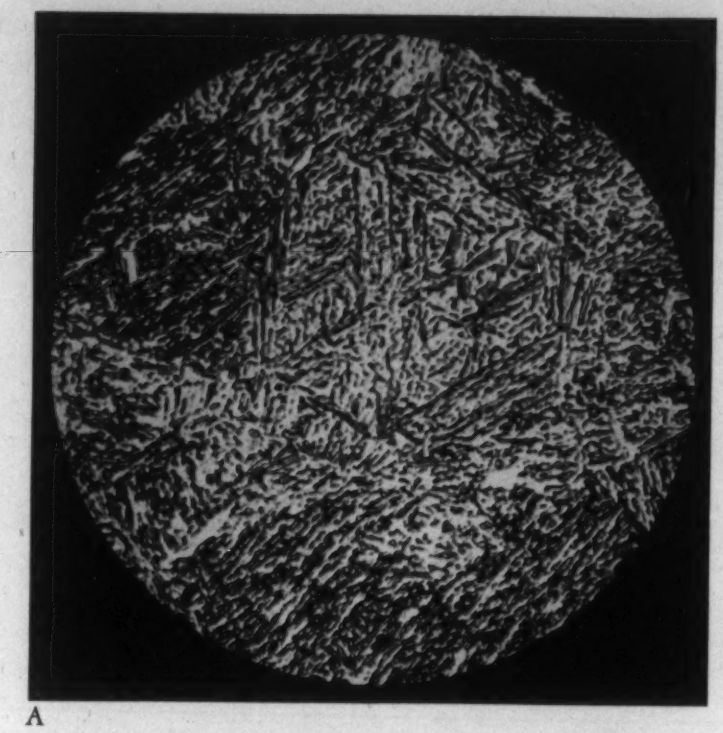
Some furnace! Capable of heat treating anything from railroad rails to wire—ferrous or non-ferrous!—E. F. C.

More "Finds" in Micrographs

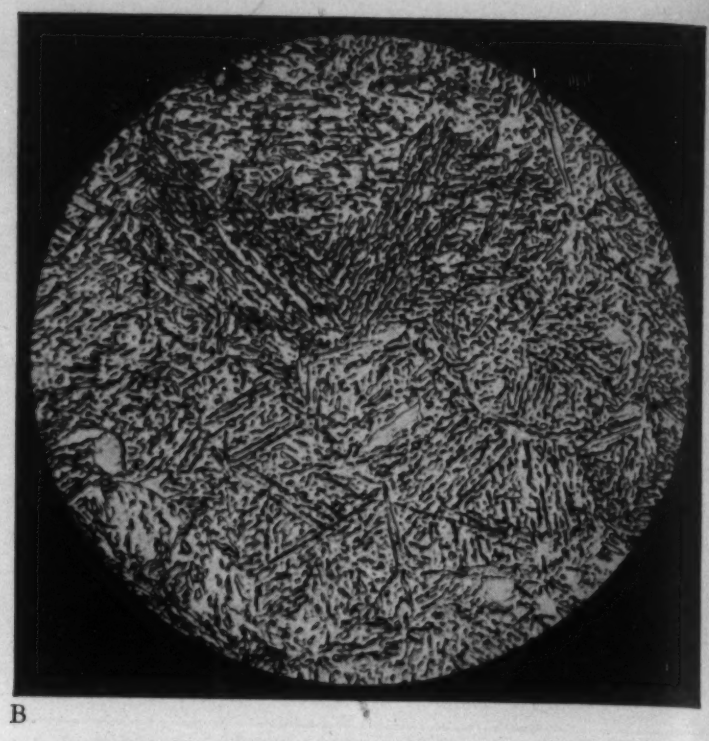
J. L. Cawthorn, Jr., of the Malleable Founders' Society, Cleveland, calls our attention to the following "finds" in



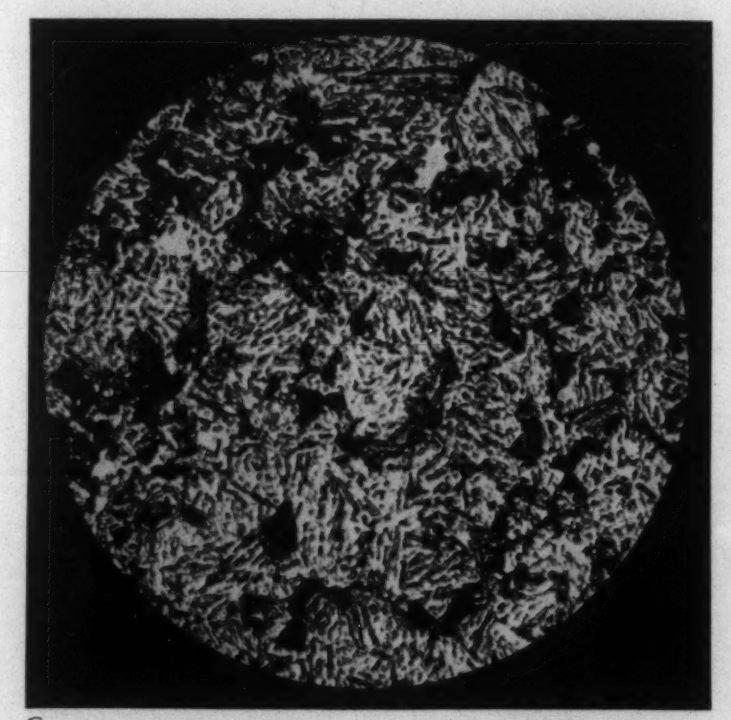
some photomicrographs, analogous to others published in this department in recent months.—H. W. G.



A



B



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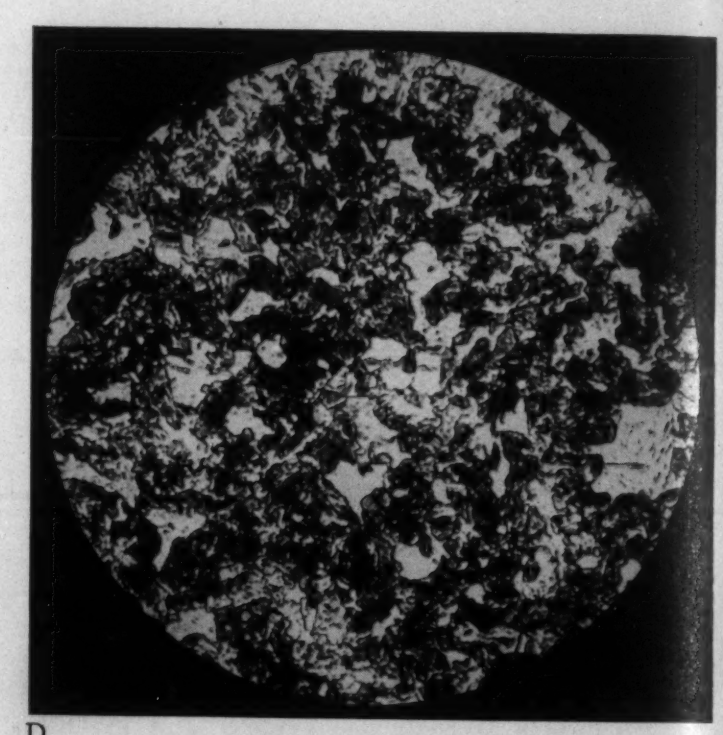

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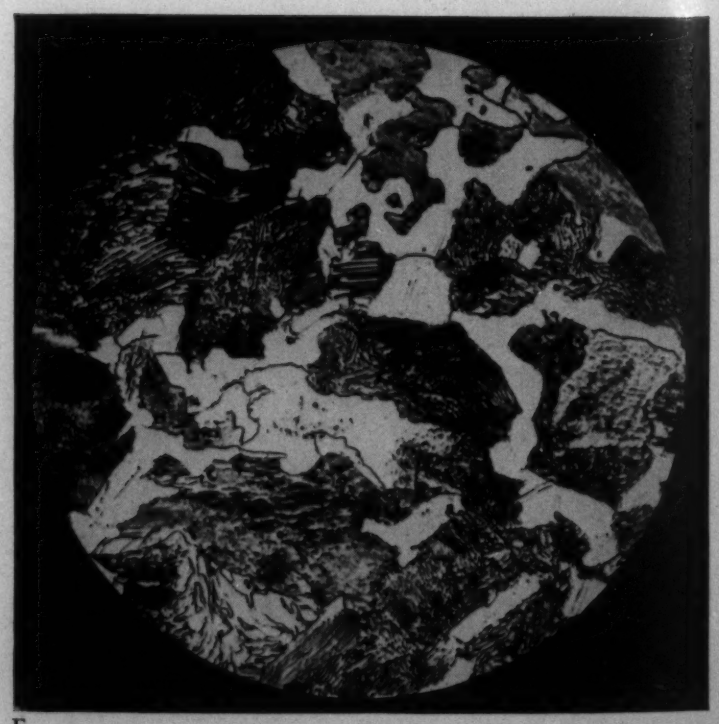
E



F

Fig. 1. Flame-hardened S.A.E. 1045 steel. ×500. (A) Immediately below tested surface; (B) App. 0.08 in. below surface; (C) Beginning of transition zone; (D) Center of transition zone; (E) End of transition zone; (F) Untreated base material.

Some Metallurgical Phases of Flame Hardening

BY R. O. DAY

Metallurgist Development Laboratory, The Linde Air Products Co., New York

THE CONSIDERABLE VOLUME of written material on the subject of flame-hardening appearing in technical literature of recent years deals largely with the various applications of the process and the different methods of procedure. The result is that very little space has been given to any discussion of the metallurgical features of the process, such as mechanism of hardening, temperature gradient, hardness exploration, and the microstructure of the hardened case. The following paragraphs will cover these subjects, although limitations of space will prohibit any great detail.

Mechanism of Hardening

Flame-hardening may be defined as a method of creating a hard surface on a suitable ferrous material by quenching after rapidly heating the surface with an oxy-acetylene flame. This is accomplished without in any way altering the chemical composition of the material under treatment. It is therefore obvious that the process can be applied only to those ferrous materials having a chemical composition that makes them responsive to quench-hardening. Thus the flame-hardening process is basically a simple heat-and-quench type of hardening involving no departure from recognized theories of hardening as accomplished by conventional furnace methods.

In the flame-hardening process, the time during which the material under treatment is held at temperature must of necessity be quite short. For example, in hardening by the progressive method of operation at a speed of 6 in. per min. with the quenching spray striking 1 in. in back of the flames, only 10 seconds will elapse between the time the flame leaves any point and the time that point is quenched by the following spray. Despite the short heating and soaking time, however, complete solution is attained to put the steel in the proper condition for quenching. The speed of operation, while fast, is not greater than the speed of reaction of steel having a normal pearlitic or sorbitic structure.

Temperature and Temperature Gradient

The temperature recommended for flame-hardening of various materials is essentially the same as that recommended for the treatment of the same material by furnace methods. There is, no doubt, a certain tendency to use temperatures slightly higher than usual in order to be sure that a sufficiently high temperature has been reached on the surface under treatment. Within reasonable limits, this practice cannot be considered as adversely affecting the material under treatment, for the careful operator of the flame-hardening process will not use excessively high temperatures.

When it is considered that the flame-hardening process creates a hardened case which has a depth of only a small fraction of an inch, it becomes obvious that the temperature gradient existing between the heated surface and the untreated base material is relatively steep. At the same time, this gradient is not so steep as to create a hardened case that changes abruptly into the base material. This change actually takes place over an appreciable depth, thus giving what might be called a "cushion effect" between the material of maximum hardness and that which has received no treatment. The existence of this temperature gradient is revealed by both microscopic examination and careful hardness exploration of the case from surface to core.

Depth of case is dependent principally on two variables—time and temperature. The general rule is that the higher the temperature or the longer the time, the greater the total penetration. The use of increased temperatures to obtain a greater depth of case frequently results in the use of undesirably high temperatures, and is not generally to be recommended. On the other hand, if the rate of heating is decreased, the time necessary to reach a suitable

Fig. 2. Flame-hardened case in a patented gray cast iron. ×500. (A) Martensitic structure immediately below treated surface; (B) Martensitic structure at depth of about 0.04 in. below treated surface; (C) Structure in transition zone approximately 0.15 in. below treated surface; (D) Pearlitic structure of untreated base.

hardening temperature must be increased. By this increase in time, increased penetration is obtained without the possible damaging effects of excessively high temperatures.

Materials for Flame-Hardening

Those materials which can be satisfactorily flame-hardened cover a wide range of steels and cast irons. As may be expected, definite chemical analyses require certain variations in procedure, particularly as to temperatures. Knowing the grade of steel or cast iron to be treated, the flame-hardening operator can produce satisfactory and desirable results from materials of a great many different analyses.

In all grades of steel to be hardened, carbon is the most important ingredient. In considering the fact that the primary object of the process is to create a hard, wear-resistant surface, it is generally advisable to use a steel containing at least 0.40 per cent C; certainly none below 0.35 per cent C. While the most common range of carbon content is from 0.40 to 0.55 per cent, particularly in applications of the progressive method of hardening, steels containing carbon up to eutectoid composition and higher are being regularly treated with complete satisfaction, by the spinning and combination methods.

It is assumed that the reader is familiar with the methods by which the flame-hardening process is applied, particularly the progressive and spinning methods. To assure a complete understanding, however, it may well be noted here that the combination method combines both the spinning and the progressive methods for the treatment of either inner or outer surfaces of cylindrical objects. The cylindrical piece to be treated is mounted in a suitable machine, preferably in the vertical position, surrounded by oxy-acetylene heating heads of suitable design and number. Rotation of the piece during treatment acts to create an even temperature around the periphery, whereas the actual hardening of the surface is accomplished by progressive movement from bottom to top.

Alloy Steels

The alloy steels that may be flame-hardened include those which may be classed as "low-alloy steels," and may contain any one or more of such elements as chromium, nickel, vanadium, molybdenum, tungsten, or copper. Such steels generally contain less than 3.0 per cent total alloying elements. Alloying elements have essentially the same effect upon the flame-hardening process as upon the furnace method of treatment. Those elements which lower the transformation points of steel necessitate the use of lower surface temperatures during treatment. On the other hand, certain alloying elements which either raise transformation points or tend toward the stabilization of carbides require a higher temperature during the flame-hardening treatment. For example, consider the difference in recommended hardening temperatures of S.A.E. 3140 and S.A.E. 6140 steels. Those steels having the lower transformation points require greater care in the control of surface temperatures when treated by the flame-hardening process because of their increased sensitivity to the higher temperatures. The one major difference in the treatment of alloy steels by flame and furnace methods lies in the choice of quenching medium. Experience has shown that many alloy steels, requiring an oil quench in furnace-treatment, may be water quenched when flame-hardened.

Cast Iron

A great many grades of cast iron, both with and without special alloying elements, have been found to respond quite satisfactorily to the flame-hardening process. Cast iron is basically a steel matrix in which are embedded numerous particles of free graphitic carbon. In the flame-hardening process it is this matrix that is hardened, the graphite inclusions playing a very minor part and remaining practically intact in the hardened material. It is therefore the carbon content of this matrix, or, in other words, the combined carbon content of the cast iron, that controls the susceptibility of the material to quench-hardening. Considering, therefore, this cast iron matrix in the light of what has just been said regarding the carbon content of steels to be flame-hardened, it must follow that the combined carbon content of a cast iron to be treated by this method must be somewhere in the range of 0.40 to 0.85 per cent.

The inclusion of the usual small amount of special alloying elements, such as chromium, nickel, molybdenum and vanadium, have little important effect upon the ability of the material to harden satisfactorily in the flame-hardening process. As in steel, those elements which tend to lower the transformation point will allow a lower hardening temperature during treatment; whereas certain of the carbide stabilizing elements will necessitate a higher temperature for complete solution before quenching. Available evidence on this subject points to the fact that both plain and alloy cast irons can be successfully flame-hardened, with little difference in final results, by giving proper consideration to the effect of the alloying elements present upon the transformation points. The importance of the alloying elements lies in their effect upon the physical properties of the material rather than upon the flame-hardening process.

Malleable Iron

The flame-hardening of fully malleablized cast

iron cannot be considered as entirely successful. In such material essentially all carbon present is in the graphitic form, the matrix being almost entirely carbide-free ferrite. The time element involved in flame-hardening is too short to allow a satisfactory reabsorption of the free carbon into the matrix to produce a uniformly hardened material. Fully malleablized iron may be given a pre-treatment of such nature that will result in the absorption of a sufficient amount of combined carbon in the matrix to allow response to the flame-hardening treatment, but in so doing the physical properties of the material are drastically altered. Some of the so-called "pearlitic malleable irons," which contain a sufficient amount of combined carbon, have been found to respond to complete satisfaction.

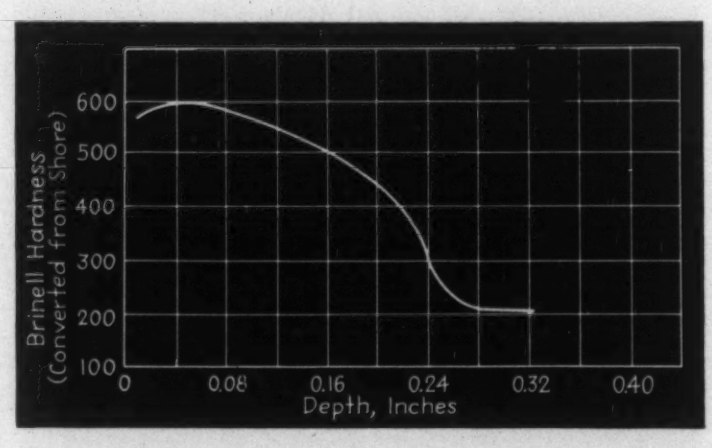


Fig. 3. Hardness-penetration curve of heavy case on S.A.E. 1045 steel.

Effect of Grain Size

The technical literature available today contains a considerable volume of information on hardenability, grain size, deep- and shallow-hardening steels, and allied subjects. These factors, other than chemical analysis, which affect hardenability under conventional furnace-treatment, have little effect upon the hardness or depth of a flame-hardened case. Essentially the same results are obtained on both coarse- and fine-grain material, both as to hardness obtained and as to depth of case under identical operating conditions. It is entirely logical to expect this for, in the flame-hardening process, such a small amount of material below the surface is actually affected that it would not be reasonable to expect the deep- and shallow-hardening properties, which are important to furnace-treatment, to play any part in the flame-hardening process.

Microstructure

The two principal means of studying a flame-hardened case are microscopic examination and careful hardness exploration from the treated surface to the unaffected core. In both of these methods of study, consideration must be given not only to the zone of high hardness but also to the transition zone between the high-hardness area and the core.

The microstructure of a fully satisfactory flame-hardened case begins at the treated surface with a completely martensitic material. This structure extends to a depth varying from one-third to one-half the total case thickness. There then appear gradually increasing amounts of another constituent which is probably undissolved pearlite resulting from insufficient heat at this depth below the treated surface. The appearance of this constituent in the martensitic matrix marks the beginning of the transition zone. This structure continues to increase in amount with a like decrease in martensite until evidence of the original structure begins to appear. The amount of original structure gradually increases until the completely unaffected core material is reached. The most satisfactory method of describing this gradual transition from hardened surface to core is by means of photomicrographs. Fig. 1 shows a series of photomicrographs taken at various depths below the surface on a section of flame-hardened S.A.E. 1045 steel containing 0.48 per cent C. Fig. 1A shows a martensitic structure immediately below the treated surface. Fig. 1B is the martensitic structure found at a depth of approximately 0.08 in. below that surface. It should be noted that this is a finer structure than that shown in Fig. 1A, indicating a decrease in temperature from the treated surface. Fig. 1C shows distinct evidence that the transition zone has begun. There begins to appear here another constituent in the matrix of martensite which is revealed by high-power examination as pearlitic in nature, indicating, as previously stated, incomplete solution at this depth. Fig. 1D shows a structure well into the transition zone. A distinct difference between this structure and any of those previously noted is readily seen. It will also be noted that some patches of ferrite are present, while the martensitic structure has almost entirely disappeared. Fig. 1E shows a structure at the end of the transition zone. The effect of some heat is readily seen, while, at the same time, strong evidence of the original structure is easily noted. The pearlitic structure of the unaffected base material shown by Fig. 1F is that a normal annealed steel of this type. All photomicrographs in this group were taken at a magnification of 500 dia.

Illustrating the microstructure of a flame-hardened case on cast iron are the photomicrographs of Fig. 2. The analysis of this iron is as follows:

TC	CC	Si	Mn	Ni	Cr
2.97	0.66	1.62	0.78	nil	0.045

Figs. 2A and 2B show the martensitic structure

immediately below the surface, and at a depth of approximately 0.04 in. below the surface, respectively. Fig. 2C shows the structure in the transition zone, while Fig. 2D shows the pearlitic structure of the untreated base. Attention is called to the fact that the graphite particles are plainly seen in the martensitic case, indicating that, in the short heating time involved, they were but slightly affected by the treatment and very little carbon was redissolved at high temperatures.

Hardness Explorations

At least as important as the microscopic examination is a careful hardness exploration of a flame-hardened case. Such an exploration reveals not only the maximum hardness but also the hardness gradient existing through the transition zone.

Either of two methods of exploration may be employed. One is to take careful and closely spaced tests across a section of a smoothly ground hardened specimen. The second, and more satisfactory method, is an exploration made on a taper-ground surface. In preparing the taper-ground surface, the author uses a specimen 4 in. long, ground to a slope of 1 to 16, this slope being sufficient to extend from the treated surface to a point well within the unaffected base material. Hardness tests are then made at intervals of 1/8 in. on the ground surface, this surface interval being equivalent to a vertical interval of approximately 0.008 in. The hardness readings obtained may then be plotted against depth below the treated surface to form a hardness-penetration curve. Fig. 3 shows a representative hardness penetration curve for a flame-hardened S.A.E. 1045 steel, the structure of which is shown in Fig. 1.

The method of hardness testing plays an important part in the final results of the test. It is essential that the hardness test be a true indication of the *surface* hardness. When a penetrator type of test is used, the shallower the penetration, the more consistent and reliable are the results obtained. Hardness tests were made by the author either with a Rockwell superficial hardness tester or with a Shore scleroscope. Actual comparisons made with various penetrator loads have demonstrated that the lighter the load the more reliable the test.

Summary

In the foregoing paragraphs certain metallurgical features of the flame-hardening process have been briefly discussed. The points of major interest may be summarized as follows:

(1) Hardening by the flame-hardening process is accomplished by a simple heat-and-quench operation, involving no departure from recognized theories of hardening as accomplished by conventional furnace methods of hardening.

(2) The speed of operation, while fast, is not greater than the speed of reaction of hardenable steel having a normal pearlitic or sorbitic structure.

(3) The temperature gradient existing during treatment must of necessity be steep. However, both hardness explorations and microscopic examination reveal the existence of a definite transition zone in which the hardened case gradually changes in both hardness and structure to untreated base material. Although the transition is generally shallower in thin cases and in alloy steels, it always exists, and at no time is there an abrupt change from hard case to untreated core.

(4) Some factors affecting the "hardenability" of steels during furnace hardening apparently play no part in flame-hardening.

(5) Flame-hardening is no more critical for low-alloy steels and cast irons than is conventional furnace-hardening. The one feature to be noted is that the localized heating in the flame-hardening process allows the use of water as a quenching medium on many steels that require an oil quench when furnace-treated.

(Editorials continued from page 139)

steels that might turn out, ten years from now, to have displaced some of the present list and to have themselves earned a place on the "significant" list.

Actually, what everybody wants to accomplish is to provide the right steel for the right use, but to do so on the basis of facts rather than caprice, and to recognize the facts that steels not in quantity demand may be the right steels, but that until the need for them leads to quantity demand, they will be more expensive.

If statistics were gathered and published on the total tonnage shipped each year of each S.A.E. composition and of other compositions called for, such a table would be almost sufficient to accomplish the desired result.

There should be a good business for a few small producers in making tailor-made products, producers geared to handle small orders that are but a pain in the neck of the large producer. There are a few such producers and it is much to the advantage of the quantity-production plants that they be encouraged. The trouble is that the quantity-producer who tries to cover the world steel market, is prone to forget, in depression periods, that these "competitors" ought to be encouraged. Instead, in order to get tonnage of any sort, he takes the specialty order at a price that gives himself no profit. These chickens come home to roost when production is up and orders from old customers for small specialty lots have to be handled with detriment to the tonnage lines.

In drawing up the "significant" list of alloy steels, great care should be taken not to put it in terms that can be misinterpreted to be chemical specifications. Changing economic conditions or temporary scarcity, may dictate substitution of an equivalent composition, and any barrier set up against such substitution is likely to be deeply regretted.

Finally, it ought to be made clear that the list relates only to wrought steels, not to cast steels. The flexibility of the manufacture of cast steels is so great that special tailoring is no handicap at all.

Actually, the steel producers have in their own records, all the data necessary. If these are turned over to the American Iron and Steel Institute for a little adding machine work, the publication of detailed, broken-down statistics would accomplish a lot in itself and it is a necessary prelude to any more formal action.—H. W. G.

Electric Steel

Certain facts go to demonstrate that the trend in the electric steel industry is definitely upward. In our September, 1939, issue we quoted an engineer, conversant with this industry, to the effect that more large electric furnaces are being installed and are likely to be installed than ever before and that the tendency will be to produce in electric furnaces some alloy steels now made in open-hearths, because, it is claimed, the trend in the cost of electric steel is downward.

In partial substantiation of this, an analysis of the annual statistics of the American Iron and Steel Institute shows that in 1929, of the total alloy steel output, 81.7 per cent was made in basic open-hearth furnaces. This proportion dropped decidedly in 1939, or in 10 years, to 71.7 per cent. One large steel company has recently ordered a 75-ton electric arc furnace and a new alloy steel company has installed two 25-ton arc furnaces.

Further testimony as to this upswing is that last year the 1,029,000 net tons of electric steel produced was the second largest ever recorded with the percentage of total steel at 1.95 per cent, the highest ever reached. Another interesting fact is that last year also the total electric steel made in electric furnaces at 23 per cent of the total alloy steel was a new high. Still another is the increase in capacity as reported by the Institute—to 1,882,630 net tons, the highest on record.

About 25 years ago the electric furnace industry in this country was in its infancy with the output a negligible total. Today American electric steel leads the world according to such data as are available, and further expansion is assured.—E. F. C.

A Chuckle

Metal for Boats

To the Editor: The following is an extract from an advertisement about boats that might be of interest in your "page of Chuckles":

E. W. Olsen

Material—Which Is Better, Iron or Steel?

Iron is best (and more expensive)—because it has greater rust-resisting qualities. Galvanized iron is practically rust proof, while steel rusts more quickly.

Exhaustive tests have proved that galvanized iron is far superior to galvanized steel or "copper-bearing" steel. *Steel is essentially iron to which certain catalytic agents have been added to speed up the process of manufacture*, thus steel can be made more cheaply than iron. However, unless these catalytic agents are in turn removed, they will cause steel to rust and lessen its life. The fact that they cannot be entirely removed is one of the reasons why steel rusts more quickly than iron. (Italics ours)

METALLURGICAL ENGINEERING news

Equipment
Finishes
Materials
Methods
Processes
Products

Alloys
Applications
Designs
People
Plants
Societies

STEELS

Worthy of special attention this month are recently-announced developments related to industry's most useful industrial materials—steels. New free-machining steels—some of special interest to metallurgical engineers in the electrical industry—a versatile new tool steel, steels capable of being machined at heat-treated hardnesses, and a new name for an old steel are notable among very recent developments.

Two New Free-Machining Steels

Union Drawn Steel Div. of Republic Steel Corp., Cleveland, has just announced two new free-machining steels—one bessemer and the other open hearth—said to be at least equal in machining qualities to the best screw steels available today.

The bessemer steel, Union Maxcut, shows physical properties and heat treating behavior comparable to S.A.E. X1112. It is said that parts have a smooth, fine finish when machined at 280 surface ft. per min. with a basic feed of 0.0095 in. and an average tool life of more than 11 hrs.

Union Multicut, the new open hearth screw steel, has physical properties similar to S.A.E. 1115. Parts show a fine finish comparable to that of bessemer screw stock when machined at 275 surface ft. per min. with a basic feed of 0.0087 in. and an average tool life more than 8 hrs. This steel can be carburized and hardened to a minimum of 60 Rockwell C and gives a tough ductile core with a minimum of distortion in quenching, it is said.

Non-Magnetic Free-Cutting Steel

A combination of low magnetic permeability and superior mechanical properties is claimed for a new non-magnetic free-machining alloy steel developed for the electrical industry by Jessop Steel Co., Washington, Pa.

Jessop Non-Magnetic Steel has a magnetic permeability of only 1.003-1.006 at 1,000 Oersteds, it is reported. Electrical resistance is high—69-71 microhms per cm. Other properties are tensile strength, 80,000-110,000 lbs. per sq. in.; yield point, 35,000-60,000 lbs. per sq. in.; elongation, 25-50%; Izod impact value at room temperature, 80-ft.-lbs. It is described as easily worked and welded, and suggested uses are in transformer, controller and switch covers, entrance plates, spacing bars, end fingers and other electrical equipment.

Machining Steels at 450 Brinell

The machining of heat-treated alloy steels with conventional high speed steel cutting tools at hardness levels once considered impractical is a modern metallurgical engineering advance that has simplified heat treating and machining practice.

Most important benefits, of course, are the possibility of machining to finished dimensions in one set up, since no distorting heat treatment is to follow, and the generally improved dimensional accuracy. Then, too, the engineer in charge doesn't have to see himself age 10 yrs. per yr. trying to find "non-deforming" heat treatments or steels.

According to the International Nickel Co., the machining of parts at 450 Brinell or higher is largely dependent on the use of nickel-chromium-molybdenum steels of the S.A.E. 4340 or similar type, which possess good machinability at high hardness, and has been facilitated by modern machine tools of more rigid construction, to insure smooth operation under heavy loads.

A typical automotive application is the use of this steel for heavy-duty truck axle shafts, which are splined on a hobbing mill at a hardness of 400-444 Brinell to avoid the necessity for re-heat treatment of the splined end after machining. The cutter speed is 72 r.p.m., with a feed of 0.0057 in. per r.p.m. and a surface speed of 84 ft. per min. An average of 46 pieces per cutter grind is obtained. In certain cases the hardness was increased to 500 Brinell, and machining was conducted satisfactorily at reduced feeds and speeds.

The aircraft industry, likewise, has been machining S.A.E. X4340, heat treated to 415-450 Brinell for propeller shafts, crankshafts, propeller spiders, under carriage parts and engine mount fittings, all of which are highly stressed in service. Instances are also reported in which industrial gear manufacturers have developed successful commercial practice for machining gears of S.A.E. 4340 at hardnesses as high as 500 Brinell.

New High Speed Steel

A special high-carbon, high-vanadium tool steel suitable for a wide variety of jobs ranging from heavy hobbing cuts to fine finishing operations is announced by Bethlehem Steel Co., Bethlehem, Pa.

Known as "Red Tiger," the new steel has a higher-than-ordinary carbon content, to give a Rockwell C hardness of 65-68 after heat treatment, without, it is said, the presence of excessive brittleness. The analysis is 18 per cent W, 4 Cr, 2.5 V, 0.60-0.80 Mo and 1.0 C. According to tests, the shock resisting properties are about the same as those of standard-carbon 18-4-1.

Standard heat treating practice without any extra precautions is used. The principal applications are said to include the machining, both rough and finishing, of such products as heat-treated car wheels and axles, heat-treated alloy steels, and cast iron. In machining heat-treated car wheels, a speed of 16 ft. per min. has been used with a 7/16-in. depth of cut and a 7/16-in. feed.

A Steel Re-Named

The low-alloy high-strength steel known to industry as "Ductiloy" will henceforth be marketed under the trade name "N-A-X High Tensile," it is announced by National Steel Corp. The steel is a product of Great Lakes Steel Corp., Detroit, a unit of National Steel.

The properties and composition of this steel have been previously described in this magazine (Oct. 1938, p. 254; Nov. 1938, p. MA 685) and will not be changed in any way under the new name.

New High-Speed Spot Welder

A new high-speed spot welder, known as the "Progress-O-Matic" welder, said to be capable of making upwards of 6,000 spot welds per hr., has been announced by Progressive Welder Co., 3081 East Outer Drive, Detroit. The first production machine, now in operation on 1941-model automobile body work, is reported to be producing better welds than are possible with ordinary welding equipment of even lower production capacity.

An entirely new method of current transfer, which makes and breaks the secondary as well as the primary circuit, provides such flexibility that assemblies of several thicknesses of metal can be welded.

All welding points are brought down on the work under full pressure and held there throughout the entire welding cycle. A longer cooling time, with work under pressure between contacts, further improves weld properties.

The new design permits such rapid distribution (timing) of current that only one transformer is required. The Progress-O-Matic method of timing welds permits timing up to 24 cycles duration, which is said to be enough to handle the heaviest type of high-production work. Interrupted timing is also possible through a few changes in the timing mechanism.

Improved Black Finish on Steel

A recently-developed improvement in the "Jetal" process (for applying a black corrosion- and rust-resistant finish to steel and iron) comprising a change to a 2-bath system is said to yield a deeper black coating and to permit simpler manipulation and control of the solution.

Two tanks of ordinary iron or steel are required for Jetallizing; no brass or copper fittings should be used. The temperature of the baths is held at specified temperatures in the neighborhood of 300 deg. F. Three water rinsing operations are involved, which may be carried out in one or more steel tanks. It is customary to use a final hot rinse to speed up the drying operation.

All steels, except those high in nickel or chromium, can be colored black by the Jetal process. Careful precleaning of the work is followed by immersion in the first Jetal tank until some coloration is noted. The work is then removed, rinsed and held in the second Jetal solution until the desired depth of blackness is obtained, after which a suitable rinse completes the process.

The time required for the Jetal dips varies from 2 min. to 5 min. in each tank. Full details are available from Hanson-Van Winkle-Munning Co., Matawan, N. J., manufacturers of electroplating equipment and supplies.

Repairing Cable-Press Cylinder

A large cast steel cylinder, of the type used in extruding lead casings on cables, recently tied up production in a large rubber plant when it fractured completely in two during operation.

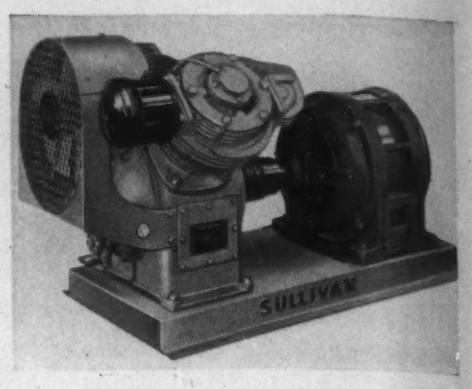
The cylinder weighs about 25 tons, and its replacement with a new steel casting would have meant a costly shutdown while the new unit was being cast and machined. This delay was avoided by repairing the cylinder promptly with Thermit welding, according to Metal and Thermit Corp., New York.

About one week was required to make the weld, including lining-up the parts, preparing the edges of the break, building the mold, preheating, pouring the Thermit steel and cooling. Machining away of excess weld metal required more time than the welding operation itself. The illustration shows the repaired cylinder ready to be re-installed.

Five thousand lbs. of Thermit and 70 barrels of molding sand were used in making the repair. The repaired cylinder has been operating 24 hrs. a day for the past 6 months at its full working-pressure load of 6,000 lbs. per sq. in., without leaks.

Small Stationary Compressors

A new small stationary compressor of precision design is being offered by Sullivan Machinery Co., Michigan City, Ind., suitable for small plants and for standby service.



The new equipment is described as compact, light-weight and smooth-running, and as requiring a minimum of floor space and power. There are 5 sizes—96 to 233 c.f.m. displacement, 15 to 30 h.p. and 30 to 125 lbs. air pressure.

New Protective Coating

A new coating material known as Microlac, for either natural or plated finishes, has been introduced by Michigan Chrome Co., 6340 E. Jefferson Ave., Detroit. The coating is practically water-white, dries to a high luster in a few seconds' time and provides excellent adhesion, flexibility and abrasion resistance, it is said.

Microlac is described as resistant to many corrosive chemicals. A unique feature is that in use it need not be mixed with thinners, as is the usual practice with similar lacquers, but is used exactly as it comes out of the container. Application may be by spray or dip, or it may be brushed on small parts.

New High-Temperature Furnaces

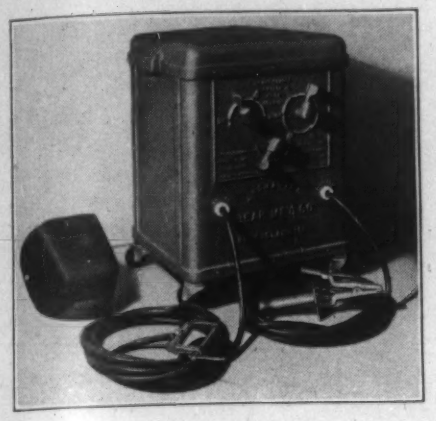
New low-cost, all purpose, gas-fired furnaces suitable for heating small stock for forging, heat treating high speed steels, alloy steels and carbon steels, and hardening and tempering punches, dies and tools are announced by Johnson Gas Appliance Co., Cedar Rapids, Iowa. The furnaces can be used for temperatures up to 2500 deg. F.

The 9 in. x 7¾ x 5 in. firebox is heavily lined with 2½ in. of insulating refractory; Carborundum hearths are standard equipment. This size of furnace is priced at $79.50. Larger sizes are also available.

● Callite Tungsten Corp., Union City, N. J., has completed the first step in its expansion program with the purchase of the business of Harris Alloys, Inc., of Newark. Thus this company will henceforth manufacture, in addition to its past products, special alloy wires such as stainless steel, Monel, phosphor bronze, beryllium-copper, brush and Fourdrinier wires.

Multiple Coil A.C. Welder

A new A.C. arc welder known as the Arcmaster, and manufactured by the Bear Mfg. Co., Rock Island, Ill., features a unique multiple-coil transformer design with reactance control, an improved safety construction and low cost. The price level is said to be about that of single-coil transformer arc welders.



The four-coil transformer construction with reactance control is said to assure an even flow of current to the electrode, and provide uniform and constant welding voltage with calibrated amperage from lowest to highest output. The manufacturer states that an operator can therefore instantly and easily strike and hold a steady arc with any size rod.

The unit is furnished in 3 models with ranges of 10-200 amps., 10-250 amps. and 10-300 amps.—all models with 220, 60-cycle, voltages.

Steel-Cutting Carbide Tools

One of industry's major weapons in its fight against delay in achieving preparedness goals will be increased dependence on carbide cutting tools to speed up production—in effect to increase available machine-tool capacity, already overburdened. The present-day applicability of certain carbide combinations to the effective machining of various grades of steel will give added impetus to this trend.

Thus, the Carboloy Co., General Electric affiliate, estimates that since the second quarter of 1939, just prior to the start of hostilities abroad, production of carbides for steel-cutting tools has jumped 60, 255, 282 and 372 per cent for each respective succeeding quarter. Cutting tools made of these materials are said to permit a doubling of production per machine-hr. as compared with conventional tool steels.

British experience with steel-cutting carbide tools as an important adjunct to Great Britain's war effort was mentioned in our June issue, p. MA 361. The George H. Alexander Machinery Ltd., of Birmingham, England, source of this information, have joined with Philip M. McKenna of McKenna Metals Co., Latrobe, Pa., in organizing Kennametal of Canada, Ltd., to engage in the manufacture of Kennametal (new steel-cutting carbide) for Canada and the British dominions.

The main office and factory of the new company will be at Hamilton, Ont. Mr. McKenna is president of the new firm, and Arthur H. Alexander of Victoria, B. C., is general manager.

Metlab's New Furnace —A Correction

On page 55 of our July issue, in a review of metallurgical engineering developments related to the national defense program, we described a newly-installed furnace at the plant of Metlab Co., commercial heat treaters of Philadelphia, which is expected to be of aid in the preparedness program there.

Through a typographical error, it was stated that "parts up to 2 in. diam." could be accommodated, whereas the furnace is actually able to take work up to 5 in. in diameter—a sizeable difference to say the least.

● Examination of the porcelain-enameled finish (after cleaning) on the refrigerator of the ill-fated submarine *Squalus* after both had spent 113 buffeted days underwater showed the finish to have been absolutely unharmed and to possess its original lustre, according to the Porcelain Enamel Institute, Chicago.

Oil Pressure Units

For circulating oil through large bearings, supplying oil to heat treating (quenching) systems and for machine-tool lubrication, The Durametallic Corp. has developed the "Durametallic" oil pressure unit. The new equipment is said to be compact, self-contained, ready to connect, and to supply oil at a uniform pressure.

The heart of this oil pressure unit is a special regulator easily adjusted by hand. In addition, the seamless copper tubing cooling coil and cylindrical oil filter are described as important in providing proper lubrication for the parts of the pressure unit and for keeping grit or scale out of the pump. A wide range of pressures, volumes and capacities is available up to 1,000 lbs. pressure, 14 qts. volume and 8-10 stuffing box capacity.

● Experience of Challenge Foundry Co., Batavia, Ill., with 150 nozzles for sand blasting equipment that they cast in "Ni-Hard" nickel-chromium iron showed their average life to be 8 times that of the previously used unalloyed chilled iron nozzles, reports the International Nickel Co., Inc.

Rubber Lining for Plating Tanks

Announcement that it has found the new Triflex "K" rubber tank lining as satisfactory for high-speed bright copper plating as it is for the bright nickel plating for which it was originally developed is made by B. F. Goodrich Co., Akron. Tests and practical experience have demonstrated, it is said, that the new lining is perfectly non-contaminating and completely resistant to the corrosive effects of copper plating solutions. Ordinary rubber or synthetic rubber linings are claimed to be deficient in these respects.

Triflex "K", a special adaptation of the 3-ply lining construction originally developed for pickling tanks, comprises a layer of hard rubber cushioned between 2 layers of softer rubber, the 3-ply being vulcanized together to form an integral structure. Adjacent sheets of the 3-ply material are overlapped to form expansion joints so that wide variations and operating temperatures are permissible. The illustration shows a section of a Triflex "K" rubber-lined steel tank emerging from a giant vulcanizer at the Goodrich plant.

Plating Metals on Plastics

Ordinarily, in producing the many composite metal-and-plastic products so widely used for automotive and aircraft fittings, consumer novelties, radio parts, machinery equipment, etc., the plastic is applied by dipping, molding or spraying on to the metal base. Comes now a new process, developed by Metaplast Corp., 244 Fifth Ave., New York, in which the two types of material are joined by plating the metal on the plastic.

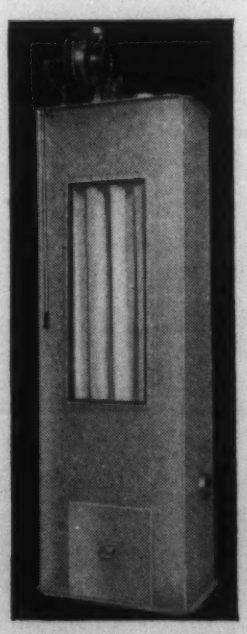
After cleaning, the plastic surfaces are given a special, electrically conducting, bonding coating, which permits electroplating with either copper or silver. Other types of plating may be "flashed" over the copper or silver base plate. Parts may be finished by tumbling, buffing or chemical dip.

Design advantages are said to be manifold—washing is possible, contrast and striking detail may be brought out, etc. In addition, the metal plate prevents moisture absorption by the plastic, may improve its corrosion resistance and hardness, and may permit the salvaging of poor-surface stocks of plastics, it is stated.

The equipment necessary is similar to that used for standard electroplating, and only a small additional installation is required. The Metaplast Co. do not sell equipment but furnish plans and specifications on a license basis.

Dust Collector

For the collection of dust created by sand blasting, tumbling, Wheelabrating, grinding and similar processes, the American Foundry Equipment Co., Mishawaka, Ind., has developed a new American assembled-type "Dustube" dust collector equipped with a hand-operated shaker and a bin hopper.



The new equipment is designed for handling relatively small volumes of air from 270 to 1440 cu. ft. per min., thus extending the size range of all existing Dustubes to meet practically any capacity. The basic design is similar to the familiar larger units manufactured by this company.

● During the last 10 yrs. the price of a typical standard blank of cemented carbide for cutting tool application has dropped from $1.00 to 38.3c per gram, and "minimum" prices for quantity lots have dropped 90%, according to Carboloy Co., Inc.

Lithium-Atmosphere Furnaces

Something radically different from conventional types of heat treating atmospheres is offered by the Lithium Corp., 175 Fifth Ave., New York, in their new Lithco atmosphere furnaces, one of which, a gas-fired unit, is illustrated herewith.

The Lithco atmosphere is said to contain a small amount of active lithium, which because it combines with oxygen more readily than does either iron or carbon, is claimed to protect the steel against both oxidation and decarburization during treatment. This protection is alleged to be complete even in the presence of amounts of oxygen or oxygen-bearing gases—carbon dioxide or water vapor—that would make conventional atmospheres strongly scaling or decarburizing.

According to the manufacturer, this is accomplished without delicate or complicated adjustments or equipment. A special lithium compound is placed in a standard cartridge and the whole inserted in a heated well towards the rear of the furnace. A carrier gas (which may be simply burnt city gas or other gaseous fuels) is swept over the cartridge, entrains the active vapor therefrom and passes into the muffle.

The amount of the compound thus introduced is said to be several times more than is necessary to "neutralize" a burnt city gas mixture, for example, and in the furnace illustrated (muffle 12 in. x 36 in. x 6 in.) the cost of the lithium compound thus consumed is estimated at $1.25 for 8 hrs. operation.

The manufacturer claims the Lithco furnace to have been completely successful in heating high- and low-carbon steels, alloy steels, tool steels and carburized steels without any scaling or decarburization, using the cheapest possible carrier gases of analyses that would ordinarily be declared impossible as atmospheres for such work. No modification or adjustment is said to be necessary, either, to correct for variations in carbon content of steel, temperature of treatment or composition of atmosphere.

● Industrial and institutional group-wash fixtures of Armco stainless steel, fabricated by Metalloid Engineering & Mfg. Co., Cincinnati, are said to accommodate 10 people in only 16 sq. ft. of floor space. The bowl is assembled in sections from 26-gage satin-finish stainless, and the base is made from 12-gage steel with a crackled baked-enamel finish.

Meetings and Expositions

AMERICAN CERAMIC SOCIETY, Refractories Division meeting. Uniontown, Pa., Sept. 6-7.

AMERICAN CHEMICAL SOCIETY, fall meeting. Detroit, Sept. 9-13.

AMERICAN MINING CONGRESS, annual western convention and exposition. Colorado Springs, Colo., Sept. 16-19.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, fall meeting. Spokane, Wash., Sept. 3-6.

ASSOCIATION OF IRON & STEEL ENGINEERS, annual meeting and exposition. Chicago, Sept. 24-27.

NATIONAL METAL CONGRESS AND EXPOSITION, Public Auditorium, Cleveland, Oct. 21-25.

SOCIETY OF AUTOMOTIVE ENGINEERS, national tractor meeting. Milwaukee, Wis., Sept. 24-25.

TECHNICAL ASSOCIATION OF THE PULP & PAPER INDUSTRY, fall meeting. Seattle, Wash., Aug. 20-21.

News of Metallurgical Engineers

Dr. F. N. Speller of Pittsburgh, consultant on corrosion (and member of this magazine's Editorial Advisory Board) has been named chairman of the American Coordinating Committee on Corrosion for the next year. . . . *Carl A. Zapffe* and *Charles L. Faust*, metallurgist and chemical engineer, respectively, of Battelle Memorial Institute, Columbus, Ohio, are recipients of the 1940 Proctor Memorial Award of the American Electroplaters' Society for their paper "Metallurgical Aspects of Hydrogen in Electroplating." . . .

Albert S. Low, vice-president and chief engineer, Austin Co., Cleveland, has been appointed to the structural steel welding research committee of the Engineering Foundation, to study problems of design and fabrication in the building field. . . . *Gordon Fox*, vice-president of Freyn Engineering Co., Chicago, has become president of the Western Society of Engineers. . . .

Tom E. Barlow, metallurgical engineer, Copper Iron and Steel Development Association, Cleveland, has resigned to become foundry engineer of the new foundry division of Vanadium Corp. of America in Detroit. His place has been taken by *J. Eugene Jackson*, for the past 8 yrs. assistant process metallurgist with Chase Brass and Copper Co., Cleveland. . . . *Carleton E. Stryker*, well-known Pacific Coast aircraft engineer, has joined the headquarters staff of the Society of Automotive Engineers to take charge of the Society's national defense responsibilities in establishing standards pertaining to aircraft and engine materials and parts. . . .

● A new aviation snip, said to make the most difficult cuts on all steel—sheet, cable, tubing and wire—up to 16-gage is announced by Penn Tool Co., 2414-25 No. Howard St., Philadelphia. The blades are beveled, of chromium-vanadium-molybdenum steel, with non-slip serrated cutting-edge hardened to 60 Rockwell C.

Metallurgical Engineering Digest

FERROUS AND NON-FERROUS

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1. Production

Blast Furnace Practice, Smelting, Direct Reduction and Electrorefining. Open-Hearth, Bessemer, Electric-Furnace Melting Practice and Equipment. Melting and Manufacture of Non-Ferrous Metals and Alloys. Soaking Pits and other Steel-Mill and Non-Ferrous-Mill Heating Furnaces. Steel and Non-Ferrous Rolling, Wire Mill and Heavy Forging Practice. Foundry Practice, Furnaces, Equipment and Materials. Manufacture of Die-Castings.

2. Processing and Fabrication

Drop and Hammer Forging, Drawing, Extruding, Stamping and Machining. Age-Hardening, Annealing, Carburizing, Hardening, Malleableizing, Nitriding, Surface-Hardening and Tempering. Heating Furnaces, Refractories, Fuels and Auxiliaries. Welding, Flame-Cutting, Hard-facing, Brazing, Soldering and Riveting. Cleaning, Pickling, Electroplating, Galvanizing, Metallizing, Coloring and Non-Metallic Finishing.

3. Properties and Applications

Physical and Mechanical Properties (including Fatigue and Creep). Corrosion and Wear. Engineering Design of Metal-incorporating Products. Selection of Metals and of Metal-Forms. Competition of Metals with Non-Metals. Specific Applications of Metals and Alloys.

4. Testing and Control

Physical and Mechanical Property Testing and Inspection. Routine Control and Instrumentation. X-ray and Magnetic Inspection. Spectrographic and Photoelastic Analysis. Corrosion- and Wear-Testing. Examination of Coatings. Surface Measurements. Metallographic Structure and Constitution.

5. General

Articles pertinent to more than one of the previous sections.

Blast Furnace Practice, Smelting, Direct Reduction and Electrorefining. Open-Hearth, Bessemer, Electric-Furnace Melting Practice and Equipment. Melting and Manufacture of Non-Ferrous Metals and Alloys. Soaking Pits and other Steel-Mill and Non-Ferrous-Mill Heating Furnaces. Steel and Non-Ferrous Rolling, Wire Mill and Heavy Forging Practice. Foundry Practice, Furnaces, Equipment and Materials. Manufacture of Die Castings.

Foundry Cores and Molds

A Composite

The application of engineering principles to foundry operations has been extended tremendously in recent years, and now reaches into every phase of the manufacture of castings—even into the once-inviolate domain of the molder himself. Today the up-to-date foundry has placed under engineering control not only its raw material metal supply, melting furnace and ladle practice, and castings-handling and cleaning, but everything else that affects the quality, soundness, structure or cost of the finished metal, including mold and core sands, binders, oils, facing materials, etc., etc.

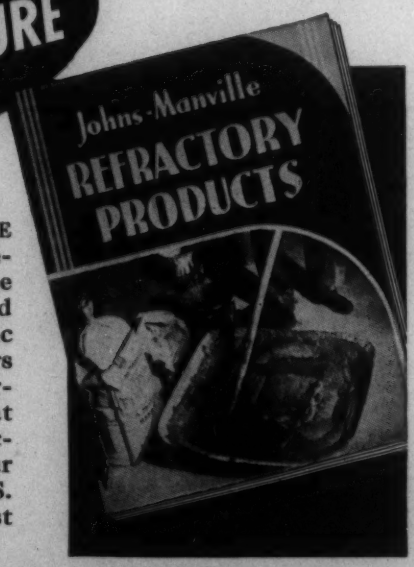
Methods of testing cores for determining the suitability of specific core oils are described by H. S. AUSTIN & C. E. SCHUBERT ("Eliminate Variables in Core Testing," *Foundry*, Vol. 68, June 1940, pp. 42-43, 122-123). The first step in testing core oils for dry sand cores is the selection of and adherence to a standard of silica sand, which should be as nearly as possible of uniform grain size and regulated angularity. A suitable mixture of silica sand, core oil and water is then prepared. One mixture that should produce 200 lbs./in.^{2} tensile strength with a satisfactory oil in dry sand cores is 1600 gm. silica sand, 50 mesh; 10 gm. core oil; 2 grains cereal binder; and 4 gm. water.

In mixing, the core oil is added to the sand and carefully mixed, then the water is added, and the mixture is rammed at least 10 times. After ramming with a standard A.F.A. rammer the cores are uniformly baked at 400 ± 5° F., dried in a dessicator, and cooled therein to room temperature (to eliminate water absorption). Before drying the cores are removed from the core plate, but only after standing on a bench for 5 min., because of the difference in contraction between the metal plates and cores.

The best results are obtained if the cores are tested for strength at a uniform temperature of about 100° F., one at a time. This temperature may be raised by individual foundries with special high-temperature core-handling problems. Also, if desired, the loss of strength of the cores after they have absorbed moisture can be determined, by testing cores after they have stood all night over a pan of water in an

New Angles on the old problem of
REFRACTORY MAINTENANCE

This FREE J-M BROCHURE



THIS FREE J-M BROCHURE will help you select the refractory materials that provide maximum dependability and efficiency under your specific operating conditions. It offers practical suggestions on furnace and boiler refractories that you will find valuable in reducing upkeep charges. For your free copy, ask for brochure D. S. 700. Johns-Manville, 22 East 40th Street, New York City.

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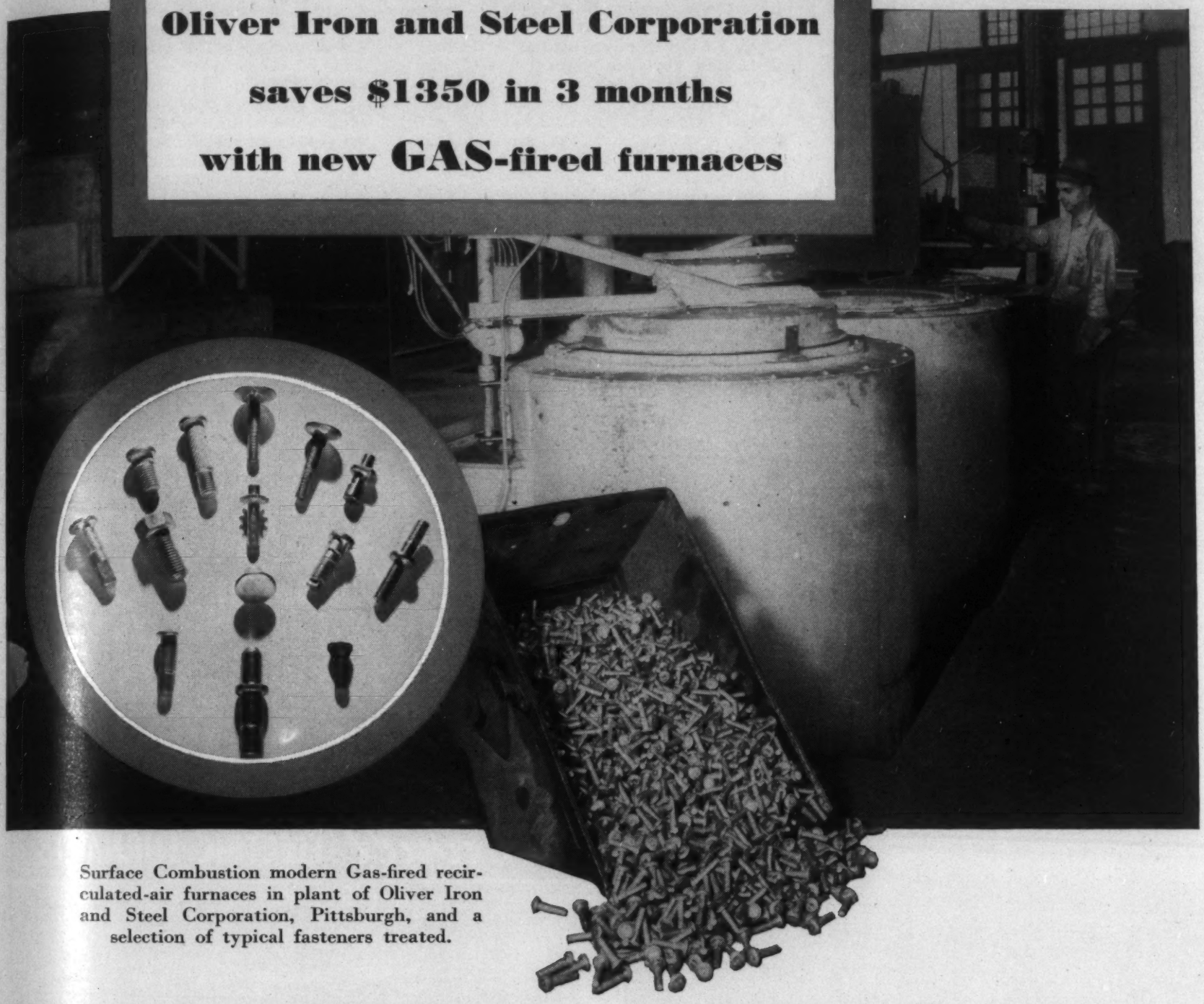
Oliver Iron and Steel Corporation saves $1350 in 3 months with new GAS-fired furnaces



Surface Combustion modern Gas-fired recirculated-air furnaces in plant of Oliver Iron and Steel Corporation, Pittsburgh, and a selection of typical fasteners treated.

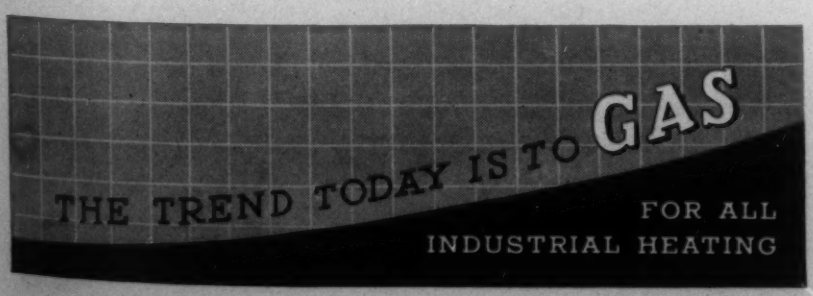
Recently the plant of Oliver Iron and Steel Corporation, Pittsburgh, replaced several recirculated-air furnaces with newly-designed Gas-fired furnaces. In three consecutive months the company saved $1350. At this rate, both furnaces will have *paid for themselves in seven months.*

The furnaces are used for drawing bolts and other fasteners ranging in diameter from ¼ to ¾ of an inch. A 1500-pound load can be heated to 1200°F. in thirty minutes. This exceptionally fast rate of heating is made possible by the recirculation of the products of combustion with a large capacity fan built into the furnace.

. . . . . .

High in heat value and capable of precise control, Gas produces perfect furnace conditions that result in a better product at materially reduced cost. And the many other advantages of Gas fuel —its speed, flexibility, cleanliness, and economy —are enhanced by the use of modern-designed Gas-fired equipment.

If you have a heat treating problem in your plant, investigate what Gas can do. Your Gas company will be glad to give you full information.



AMERICAN GAS ASSOCIATION

INDUSTRIAL GAS SECTION

420 LEXINGTON AVENUE, NEW YORK CITY

oven at 70°-80° F. If the cores test below 70 lbs./in.^{2}, the binder is made of deliquescent material and the cores will cause blow holes in the castings.

It is important to know the amount of gas given off by core binders when surrounded by molten metal. This is determined by placing a 5 gm. used tensile test sample of the core in an alundum boat in a tube furnace at 1920° F., sealing one end and collecting the bases over water in a calibrated cylinder; after running the necessary blanks, the amount of gas given off by the binder is easily calculated. [Accurate results require a number of other precautions not mentioned by the authors.—S.W.B.]

Synthetic molding sand has proved a practical success in England and America. According to A. TIPPER ("Synthetic Molding Sand," *Foundry Trade J.*, Vol. 62, Feb. 8, 1940, pp. 119-122), at least half of the American steel, cast iron and malleable foundries use this type of sand. [This figure seems too high, at least for gray iron foundries.—J.W.B.] Suitable sands should be evenly graded, with low proportions of both coarse sand and silt, and should be free of fine clays or mineral matter, which are easily dehydrated. Refractory clay or iron compound grain coating improves the bond, and, of course, good refractory properties are essential.

The use of two or more sands mixed together is inadvisable unless special factors such as cost, surface finish required, or advantages of some natural-bonded material outweigh the importance of permeability, dry strength and freedom from "silting-up."

The best bonding materials are said to be the colloidal clays, with the American bentonite superior for producing green and dry strength, weight for weight. Certain coal-distillation products also have definite bonding merit in either natural or synthetic sands, and the addition of fine coal dust improves casting finish and sand condition. A number of so-called "organic" bonding agents (like concentrated sulphite lye, molasses, dextrine, etc.) are also used in molding sands to improve the working properties.

Although synthetic sand offers many advantages—lower sand-handling cost, less chance of blowy castings, higher casting production rates, possibility of re-using old sand, etc.—it has its disadvantages, too. These are high first cost, rapid loss of moisture, occasional balling-up, likelihood of poorer surface finish without special precautions and necessity for strict control.

Moisture control is the most important step in the preparation of sand for molding, but other factors, often related to it, have much influence. WM. Y. BUCHANAN ("Sand Testing with Special Reference to Deformation," *Foundry Trade J.*, Vol. 62, Mar. 14, 1940, pp. 199-202), discussing compression testing, sees no need to modify his earlier conclusion that the 2-roller type of mill is the most important in any clay-bonded sand preparation plant.

The rate of loading does not seem to have much effect on the compression strength as found with the 1⅛ in. test-piece, but working with the A.F.A. test-piece and measuring deformation it is better to avoid variations in the rate of leading. By ramming the A.F.A. test-piece while allowing the tube to move with the last blow, the hardness distribution is materially improved. The 1⅛ in. diam. by 2¼ in. test-piece is now being used for high-temperature work in preference to the 2-in. diam. It is rammed by double compression, or so-called double-end ramming, using a special A.F.A. rammer. The test-piece should be made by simple pressure and not by blows of a mallet.

The author's "index of ramming" is a number found by multiplying the ratio of the density of the porous rammed sand to the true density of the sand materials by 100, and then deducting 42. By using the A.F.A. test-piece made by drop-weight and the A.F.A. test by index of ramming, the true effect of flowability can be separated, and the effect of the degree of ramming studied.

Deformation is definitely related to the percentage flowability, and it should be used as a method of judging mixing efficiency. The A.F.A. compression test is affected by flowability, and this should be taken into account when assessing the value of such variables as moisture, milling, grain size, grain distribution and bond.

X (1)

1a. Ferrous

Making Steel Castings

A Composite

The use of steel castings in the landing gear assembly of one type of large commercial airplane is typical of the quality standards that steel foundrymen are now successfully meeting. Throughout the transportation and other industries the cry for light-weight design has increased the amount of cast steel in use, but the demand for smaller sections has added to the problems of the steel casting manufacturer.

Some of the difficulties have been suc-

THE CRANE CO., CHICAGO

regularly manufacture 45 non-ferrous and 12 ferrous alloys for use in their various manufacturing processes.

Ajax-Northrup Furnaces are used extensively because of their flexibility and precision control and because laboratory developments can be transferred to large scale factory production with larger Ajax-Northrup Furnaces with predetermined results.

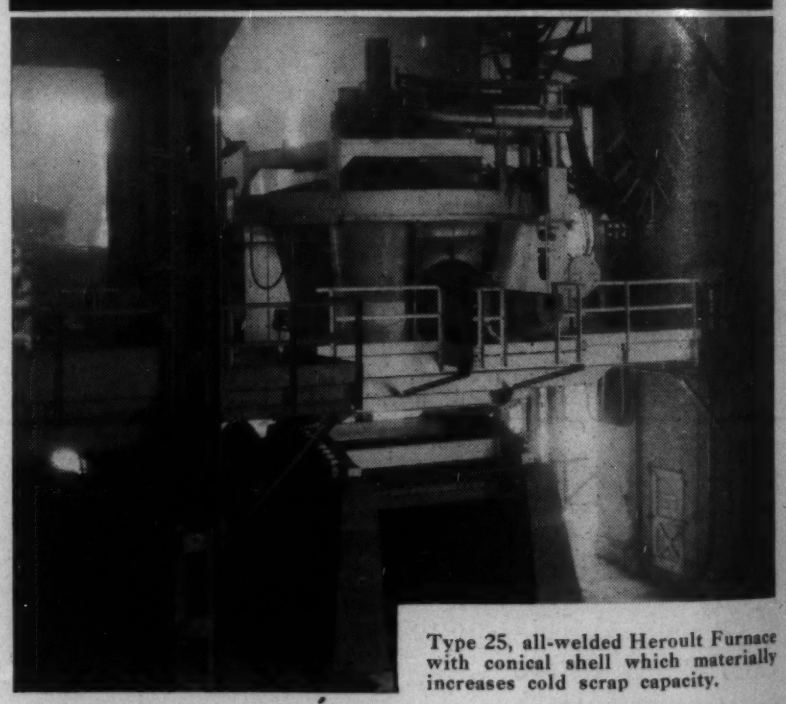
The illustration above shows one of two Ajax-Northrup tilt type high frequency furnaces supplied with power from a 111 KW high frequency generator. Ajax-Northrup lift coil type furnaces are also used for material testing.

Information of special interest to laboratory and metallurgical executives will be sent on request.

Ajax-Northrup Melting Furnace Capacities: One Ounce To Eight Tons

AJAX ELECTROTHERMIC CORPORATION
AJAX PARK TRENTON, N. J.

Heroult ELECTRIC FURNACES



Type 25, all-welded Heroult Furnace with conical shell which materially increases cold scrap capacity.

For low-cost, efficient melting and refining of all kinds of ferrous materials by either basic or acid process—including alloy, tool, and forging steels, iron and steel castings. Any capacity from ½ ton to 100 tons; hand, chute, machine or drop-bottom bucket charging.

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General Offices: Pittsburgh, Pa.

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Columbia Steel Co., San Francisco, *Pacific Coast Distributors*

United States Steel Export Company, New York

UNITED STATES STEEL

INTERVIEW WITH A PILE OF BLACK SAND

1.

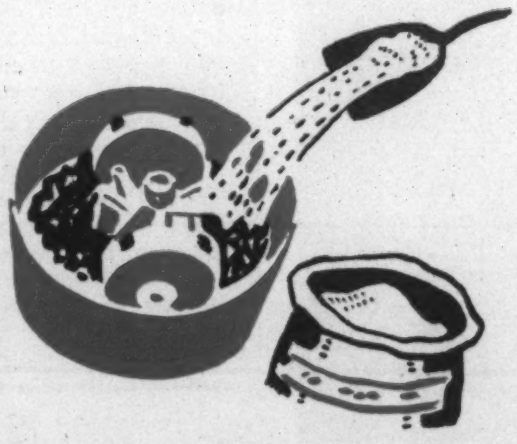
The boss was just talking to a truckman, so I guess I get the gate.

2.

Nope, looks like I'm in again! Here comes new sand and Truline Binder to put me back on the job.

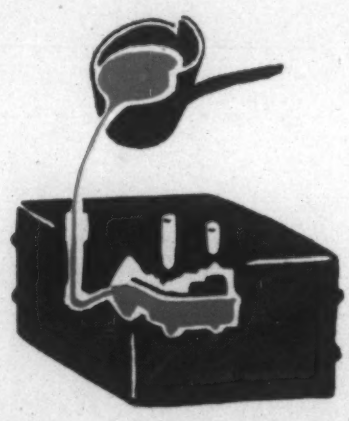
3.

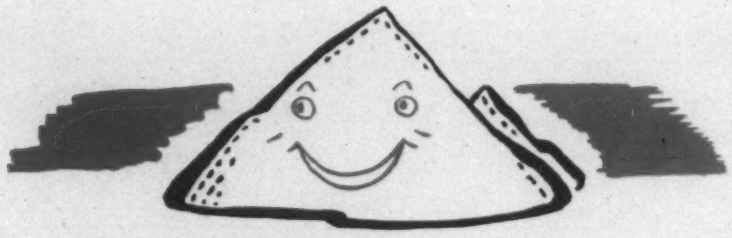
Watch me save the boss some cash, teaming up with that low-cost Truline Binder and new sand. I'll make swell castings, too.

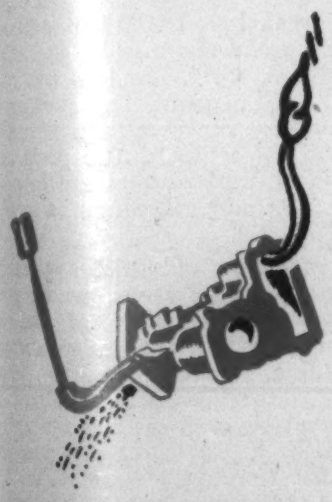


4.

This is the life! Come on, you hot metal, I can take it. Truline makes me as good as new.







5.

Look at that casting . . : smooth, clean, and without a crack. I hardly felt the metal shrink, the way Truline burnt out and let me collapse.

6. Well, here I am at the old dump. I lost some weight in the reclaimer, but thanks to Truline I'll mix into a lot more good cores. Thanks, boss, you did a good job for both of us.

TRULINE BINDER

Reg. U. S. Pat. Off. by Hercules Powder Company

CAN BE USED WHEREVER METALS ARE CAST

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HERCULES POWDER COMPANY

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U-29

There's a lot of truth in this little interview. Foundrymen everywhere have learned the merits of Truline Binder. It is being used in ever-increasing quantities in steel, gray iron, malleable iron, and non-ferrous foundries to save money and time, and to get better castings. Ask about Truline Binder for cores, and as a core wash, too.

We'll be at the Foundry Show—Booth 56. Look us up.

cessfully overcome by better melting, pouring and molding practice, some recent advances which are reviewed by C. H. LORIG of Battelle Mem. Inst. ("Cast Steel —Effect of Additions on Quality," *Product Eng.*, Vol. 11, June 1940, pp. 258-259). For example, it has been found by Sims and co-workers that low ductility in cast steel is invariably associated with network or eutectic distribution of non-metallic inclusions, particularly manganese sulphide. Treatment with *large* amounts of aluminum greatly improves the ductility.

With no aluminum the manganese sulphide inclusions are globular and not harmful. With small amounts of aluminum the sulphides are precipitated in a network or eutectic form that results in low ductility. With larger amounts of aluminum (more than 0.03%), the harmless aluminum sulphide type of inclusion is formed, and ductility is satisfactory. Ductility may be further augmented by introducing calcium with the aluminum.

The utility of calcium for destroying grain boundary network inclusions is echoed by H. BIER ("Deoxidizers Used in Steel Manufacture," *Foundry Trade J.*, Vol. 62, Apr. 25, 1940, p. 309), who finds, however, that this addition consistently [and unaccountably] gives coarse-grained steel. Zirconium treatment was beneficial for almost all alloy steels, the advantage being evident in improved impact strength and uniform, intermediate grain size.

Lorig mentions the development in the last year or two of certain exothermic compounds for introducing various alloying elements into cast steel or iron; these compounds ["Fer X", "Chrom X," etc.—see METALS AND ALLOYS, Feb. 1940, p. MA 68; June, p. MA 372] cause the various alloys to melt immediately, without chilling the bath.

Ford is now regularly producing all truck ring gear blanks and will soon be making all cast ring gears and transmission cluster gears by casting the alloy steel centrifugally. The lack of directional properties in the castings makes them more durable than forgings. The applications of steel castings in the Ford tractor are described, and their manufacture reviewed by R. H. MCCARROLL & E. C. JETER of Ford Motor Co. ("Cast Steel Parts for the Ford Tractor," *Metal Progress*, Vol. 37, May 1940, pp. 521-526). Pouring of the castings is continuous, electric holding furnaces being used for the metal, with conveyor reels for bringing the molds direct to pouring spouts.

The equipment for centrifugal casting of passenger car gear blanks mentioned above has been adapted to the production of 3 tractor transmission gears and tractor differential gears. Four rotary casting tables, each carrying 18 centrifugal dies, are supplied from a 10-ton holding furnace fed by a 15-ton electric melting unit. The top section of each centrifugal die is removable, and a conveyor circulates spare dies, supplying the rotary casting tables.

Forehearth cupolas are used to melt steel for the automatic crankshaft casting. Metal is poured from the cupolas (really stack-charged air furnaces fired with powdered coal) at low temperatures, about 2750° F., to save refractories, then brought up to pouring temperature in a 15-ton electric furnace, from which it is transferred to a coal-fired holding furnace. The metal then flows into a pouring car and is poured automatically into crankshaft molds.

The bulk of the tractor castings is made of a copper steel containing 0.35-0.45% C, 0.50-1.50 Cu, 0.20-0.40 Si, 0.70-0.90 Mn, 0.05 max P and 0.05 max. S. Most of the parts are annealed to 163-217 Brinell and water-quenched and tempered to give maximum toughness. Green sand is the most widely-used mold material. Dry sand molds are used for very heavy castings requiring close dimensional accuracy. The permanent molds for centrifugal castings are low-carbon steels, containing chromium or molybdenum or both.

Another important industrial application of steel castings is for valves, where pressure-tightness and durability at elevated temperatures are vital. The design, composition, molding, melting, pouring, heat treating and inspection factors present in making dependable steel castings for valves are discussed by J. J. KANTER of Crane Co. ("Steel Valve Castings," *Iron Age*, Vol. 146, July 11, 1940, pp. 29-33). Controlled directional solidification—feeding the molten steel to the mold in such a manner that the lighter and "thin-walled" portions fill and solidify first, so as to permit the heavier sections to act as metal-feeding reservoirs during the former's volume contraction—is the key to the successful manufacture of high-grade pressure units.

Small steel pressure castings, always a difficult problem, are best melted in high frequency induction furnaces, which permit of rapid melting and production of small heats under close control. A detailed discussion of induction melting, as applied to the production of pressure castings, is given by H. W. MAACK, also of Crane Co. ("Modernized Steel Castings Foundry Increases Efficiency and Production," *Valve World*, Vol. 37, Jan.-Feb. 1940, pp. 9-13).

Storage battery room in a broadcasting studio. Lead grid visible inside the battery in the foreground. Four hundred of these 18" high batteries are available for emergency power.

LEAD Stand-By BATTERIES

In major emergencies, when floods, hurricanes or earthquakes disrupt normal power, lead-acid batteries are the dependable source of reserve power.

Broadcasting studios, central lighting stations, factories, mines, telephone and wireless communication services have great banks of reserve power in the energy of their lead-acid battery emergency resources.

Lead storage batteries perform numerous duties less dramatic, but, indeed, no less necessary. Their function in an automobile is well known. They also furnish power for operating submarines, industrial trucks, mine locomotives, drawbridges, etc. Today, countless farms are electrically lighted by them.

In the manufacture of lead storage batteries, to whose total weight lead contributes as much as 65%, 198,000 tons of lead were used last year. A considerable part of this tonnage came from the mines of this Company—the country's largest producer of pig lead.

ST. JOSEPH LEAD COMPANY

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ELdorado 5-3200

Kanter points out that because of knowledge provided by radiographic inspection, it is now possible to make small standard-line castings entirely free of objectionable defects. One important type of defect whose frequency has been diminished through better design are "hot tears," discussed by WM. J. PHILLIPS of Symington-Gould Corp. ("Prevent Hot Tears in Steel Castings," *Foundry*, Vol. 68, July 1940, pp. 27-28, 87-89.) Information on the rate of contraction of steels in the hot-tear range (around 2375° F.) as well as on their strength at such temperatures also aids in eliminating hot tears.

Phillips discloses experimentally still another factor that may be the cause of hot tears in castings that have been successfully produced with standard core and mold practices, but which occasionally tear when poured under apparently identical conditions. In such cases, the castings that tear are usually those poured from the last portion of metal in the ladle, and in such castings a characteristic type of inclusion [illustrated, but that's all] was always present. Castings showing only inclusions of the Al_2S_3 type described by Sims were free of hot tears. X (1a)

Producing "Acceptable" Steel

A Composite

Meeting their customers' ever-increasing and constantly more complicated requirements as to composition, dimensions and quality of steel has caused the steel industry's metallurgical engineers no end of headaches and harangues. At the recent meeting of the American Iron and Steel Institute, three of them discussed the control factors involved in manufacturing steel for industry's diverse needs and specifications and made separate but similar pleas for more intelligent cooperation between steel maker and steel user.

The problem as to composition is resolved into the question "Must we design the part to use existing steels or must we design the steel to fit a method of (part) manufacture?" by EARLE C. SMITH of Republic Steel Corp. ("Control of Steel Composition and the Problem it Presents," *Paper, Am. Iron & Steel Inst.*, May 1940, 24 pp.) Customers, he believes, should be asked to assist in this effort by taking existing materials into account when developing new designs rather than by forcing the steel producer to alter his product to meet the requirements of a particular design problem.

Methods of melting steels of all types, refining practices, ingot-freezing, etc. lead to non-uniformities in steel chemistry that cast strong suspicion on the wisdom of our practice of making and buying steel to narrow chemical specifications. In most cases broader composition ranges for individual elements would suffice, and would simplify the steel-manufacturing problem.

The number of steels commonly produced (excluding tool steels) exceeds 1,000 and the total number of steels made in any quantity, however small, must be nearly 5,000. Actually, only about 200 of these compositions are necessary as separate entities for most applications. Simplification and standardization are long overdue, and consumers should be encouraged to use more of those steels that are now large-production items in place of many hundreds of small-volume, high-cost special steels.

There is already a growing practice of specifying and ordering steels on the basis of either suitability for intended service or desired physical characteristics, without reference to composition details, and this tendency should be carefully cultivated.

Manufacturing practices involved in meeting physical test requirements are discussed on the basis of a classification of steels into those not to be heat-treated, and those to be heat-treated or cold-processed, by C. H. HERTY, JR. of Bethlehem Steel Co. ("Producing Steel to Meet Physical Test Requirements," *Ibid.*, 17 pp.) Even though scientific controls have been of great help to the melter, steel-making is far from an exact science. Smith's contention that unnecessarily narrow composition ranges are fundamentally dangerous to the industry is supported by data showing the high percentage of off-grade heats that will occur even in a modern, highly-controlled mill manufacturing to closely restricted chemical specifications.

If the consumer would modify his more or less inflexible manufacturing program, much of the increased cost of steel production would not be necessary, and both producer and consumer would benefit. The ultimate costs involved would be much lower if both producer and consumer were to share the responsibility for obtaining the maximum yield of usable steel at the minimum cost.

Steel-consumer cooperation in specifying dimensional tolerances also is asked by A. C. CUMMINS of Carnegie-Illinois Steel Corp. ("Dimensional Variations in Hot-Rolled Steel Mill Products and the Problem of Control," *Ibid.*, 28 pp.) At the same time, users are promised continued progress in the steel-producer's ability to manufacture hot-rolled products to ever-narrow tolerance ranges.

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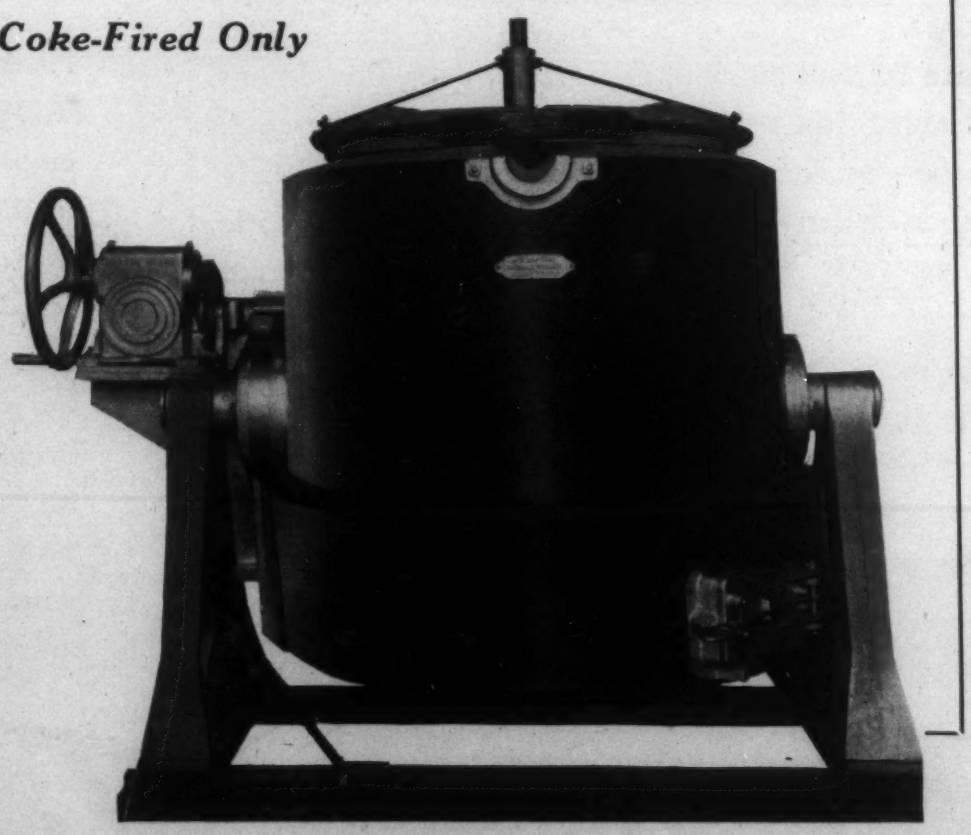

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constant and uniform finishing temperatures in rolling. A likely solution may be in using the present type of reheating furnace to raise the temperature of the steel to a temperature 100° or 150° F. below the rolling temperature, and then use a supplementary electric furnace, of either the direct resistance or high-frequency induction type, to bring the steel to rolling temperature. This would also aid in the control of scaling and decarburization.

The small-order item is a major obstacle in the control of size variations and the establishment of better tolerance standards, and non-standard sections add to the difficulties. The cooperation of the steel user in providing better rolling schedules will shorten the time necessary for the establishment of the necessary improvements.

FPP (1a)

Centrifugally-Cast Pipe

"Manufacture of Spun-Iron Pipes." S. Spray. *Foundry Trade J.*, Vol. 62, Apr. 25, 1940, p. 308. Review.

The first patent on centrifugal casting was taken out in 1809, but the experimental development of the process as applied to pipe making was originated by de Lavaud in 1914. Commercial development did not achieve large-scale status until 1922, when the Stanton Co. erected a plant which has been operated ever since, for the manufacture of spun-iron pipes. The process was later taken up by firms in America, France and Germany.

The Mairey process consists of the feeding of a stream of finely-powdered ferro-silicon into the mold just ahead of the molten metal. In the absence of this, the molten iron becomes chilled immediately on coming into contact with the water-cooled mold, making cutting, drilling and tapping of the pipe very difficult. The process is said to prevent chill formation in two ways: The air between the particles of powder expands and forms an insulation between the metal and the mold; and the ferro-silicon aids the precipitation of graphite from the molten iron.

In the old process a high temperature was necessary to split up the cementite present in the pipe; even so, the graphite was precipitated in nodular form. With the Mairey process the outer half of the section has a non-brittle dendritic structure, resulting in high values of tensile strength and impact test. Much less severe heat-treatment is required as only pearlite has to be split up.

In pipes having a thin wall, as for example a 2 in. diam. pipe, the metal has a dendritic structure throughout the whole of the section, and gives a ring-test tensile strength of 57,000 lbs./in.^{2} AIK (1a)

Slivers in Cold-Rolled Strip

"Slivers in Cold Reduced Strip." Paul J. McKimm. *Blast Furnace Steel Plant*, Vol. 28, Mar. 1940, pp. 243-246, 252; Apr. 1940, pp. 338-340. Investigation.

Slivers are the most troublesome defects commonly encountered in the production of cold-reduced strip, as they can be detected only after stretching a sheet. After elongation, they are often evident to visual examination when the strip is rubbed with emery cloth across the rolling direction. Poor quality steel can cause slivers, but this is generally not the cause, as defective steel is usually discovered in the early stages of processing.

Study of normal quality slabs charged cold into the reheating furnace and heated to 2230° F. in an atmosphere containing 7-11% oxygen showed that numerous minute fissures were produced on the surface of the oxidized steel in the roughing mill. These appeared as slivers after cold reduction. The checking condition gradually decreased with gradual reduction in oxygen content of the furnace atmosphere. No checking occurred when burning oil if oxygen was maintained under 3% and the flame was controlled so that heating began earlier (thereby insuring a longer soaking period) without any increase in total heating time.

To obtain good hot strip, the steel should be soaked at the correct temperature. It should not be washed, but well soaked and uniformly heated in an atmosphere sufficiently oxidizing to form a layer of scale that can be readily cleaned at the scale-breaker and first spray. Tests with furnace atmospheres containing no oxygen, using oil and natural gas as fuel, showed that the scale became so tight that it could not be cleaned, and scale slivers appeared.

Another type of sliver results from "digs" or "snowballs," generally attributed to rubbing of the piece on the hot-mill run-out table apron plates or to a tightening of the coil, causing one strand to be vigorously stretched over another and to embed scale in the strip surface. Smooth rolls in the roughing unit do not produce a suitable surface and these should be roughened. Residual copper may aid in promoting a sliver effect. MS (1a)

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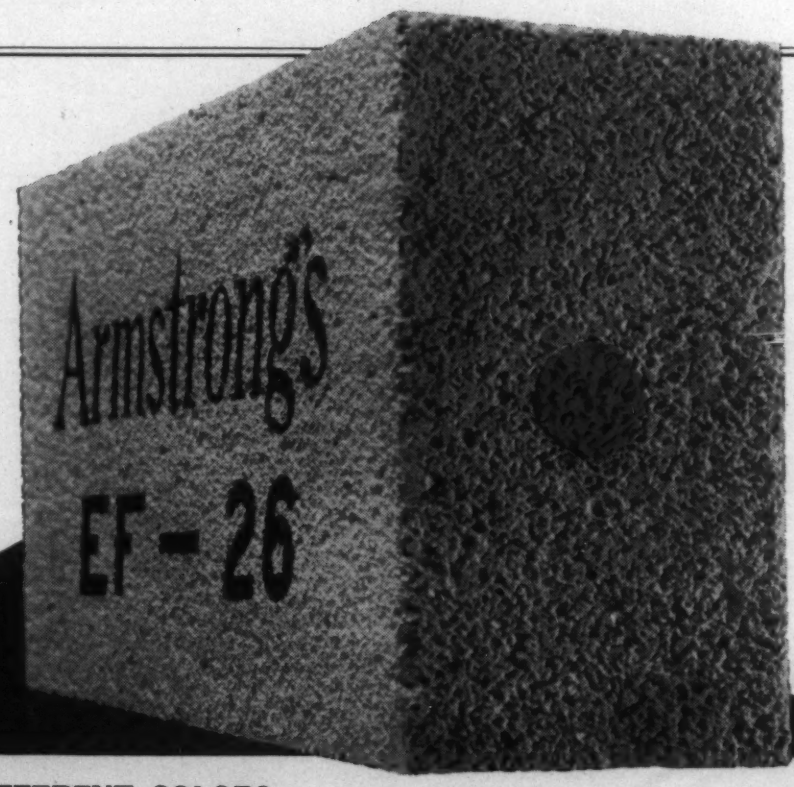

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1b. Non-Ferrous

Making "Nickel Silver" Castings

"Producing Castings of Nickel Silver." D. M. Curry. *Foundry*, Vol. 68, June 1940, pp. 46-47, 123-127. Descriptive.

The term "nickel silver" applies to metals containing 10-30% Ni, 5-45 Zn and remainder copper. [If the unambiguous term "nickel brass" were generally adopted to replace "nickel silver," space-wasting prefatory definitions like the foregoing could be dispensed with.—Editors.] At least 20% Ni ensures tarnish resistance and gives a white color. Zinc between 10 and 20% should meet most foundry requirements. The lower limit is used for maximum soundness in pressure castings of uneven design; increase of zinc raises the yield point, ultimate strength and hardness, and decreases the ductility.

A small addition of tin is desirable to improve density, refine the grain, increase fluidity and prevent "lead sweat" (if lead be present). Lead may be used up to 7%. For ornamental work, up to 3% Al is sometimes used; the alloy then is susceptible to heat treatment. About 0.25% Mn is of advantage as it deoxidizes the metal and improves soundness. Magnesium and phosphorus are also used as deoxidizers, but the amounts added should be consumed by the reaction. Sulphur contamination from any source should be avoided.

Melting should be rapid and under slightly oxidizing conditions. The best type of furnace to use is either a forced-draft coke type or an oil-fired unit. Oil-fired crucible-type furnaces are rapid melters and can be operated easily to give a desired slightly oxidizing atmosphere. Crucibles are usually of the plumbago type.

Force-draft coke-fired furnaces are also suitable. In melting in such furnaces, the bulk of the charge is contained in the pot at start of firing. Natural-draft furnaces are not as satisfactory for these alloys as forced-draft because they are slower and usually give a reducing atmosphere, which results in hydrogen pickup.

In deoxidizing, the manganese should be bound to the bottom of a steel rod and plunged to bottom of crucible at least 5 min. before drawing from the furnace. Similarly, the magnesium addition should be made immediately before drawing. Phosphorus is added just before pouring and after the protective slag has been removed. Glass, rather than charcoal, should be used as cover. When prepared ingot is used, deoxidation with manganese or magnesium will suffice. No other kind of deoxidizer, especially silicon, should be used.

Before drawing, the metal should be superheated to at least 2550° F. and should be evolving zinc fumes freely. After drawing, the slag should be thickened if necessary with dry sand. The metal should be poured hot into the molds—from 2250° to 2450° F. Horizontal pouring is preferred. If the metal rises in the runner at, or prior to solidification, the melting or deoxidation practice has been defective, and the castings will be porous. VSP (1b)

Air Control in Lead Smelting

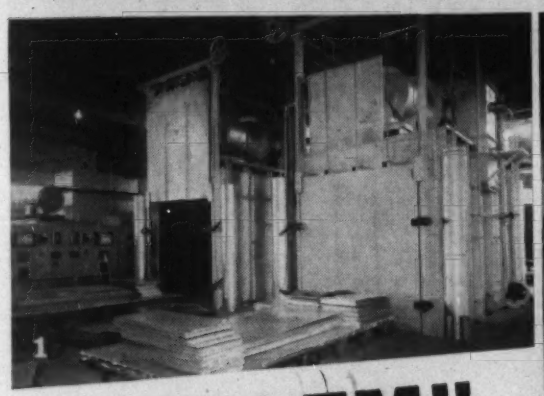
"Contributions to the Art of Smelting Lead Products." Virgil Miller, R. Bainbridge & R. Ellison. *Bur. Mines Rept. Investigations* No. 3512, July 1, 1940. Research.

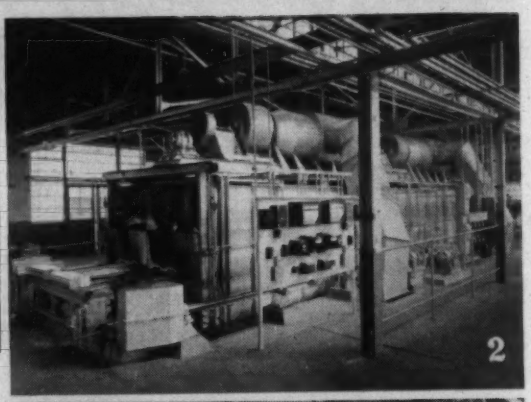
Air control has been successfully applied to iron blast furnaces, to cupolas and to other types of metallurgical equipment. Control of the air used in lead furnaces has been widely debated. This report compares volume control and pressure control of the air supplied to lead furnaces.

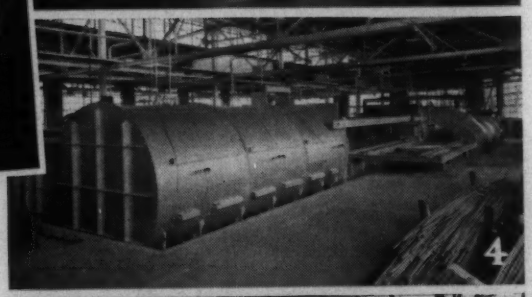
At the Trail smelter, there is a straight line relationship between the lead content of the slags and the average temperature at the tuyere zone. For every 1% lead increase in the slag, the average temperature at the tuyere zone decreases approximately 210° F. By increasing the number of tuyeres a better air distribution is obtained, and less free oxygen passes through the charge. Scrap iron is very effective as a flux for smelting barred-off accretions and for enlarging "blow holes".

Lead blast furnaces give better recovery of lead bullion per unit of material charged when air is supplied by pressure regulation. As the blast furnace stock column gets tighter, the volume of air going through the charge becomes less, and as the charge loosens the volume of air increases. With pressure regulation, the fluctuations in air volume vary with the physical condition of the charge and, therefore, this method of control makes for a minimum variation of the furnace shaft temperatures.

When air is supplied by volume regulation, a definite volume of air must pass through the charge. The passage of a constant volume of air through charges compacted to different degrees makes for a greater variation of furnace shaft temperatures. With such variations more "hot tops" would be expected as well as an increase in the amount of lead volatilized. Less lead per blast furnace charge then would remain in the furnace to be reduced to metal. (1b)







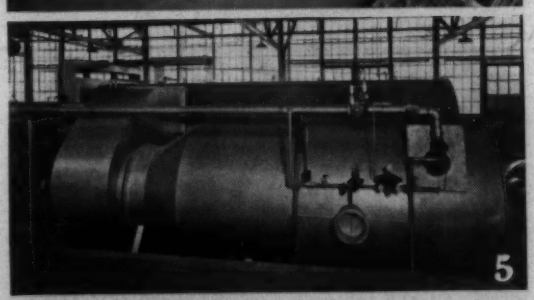


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Photo 3—Car Type Furnaces. Convection unit located along side furnaces.
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Photo 5—Shows the new type convection unit.

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Metal Coloring

"Metal Coloring Theory and Practice." Joseph B. Kushner. *Products Finishing*, Vol. 4, Jan. 1940, pp. 9-17; Feb. 1940, pp. 32-38; Mar. 1940, pp. 46-50; Apr. 1940, pp. 34-42; May 1940, pp. 38-47; June 1940, pp. 66-72. Descriptive.

Reflection from metal surfaces is classified as specular, diffuse or diffractive, depending on whether the light is sharply reflected, scattered or results in a diffraction pattern. Absorption or interference effects are the causes of colors on metals. Refraction of the extremely thin metallic layer is the cause of the interference color effects.

With respect to gold, the shade of color of the metal as deposited from a plating bath is influenced by too many factors to permit an exact designation of the shade that will be obtained. The author recommends certain formulas for the various commercial shades of gold plating. For yellow gold, the bath is capable of producing so many shades that it is best to leave a margin of color control. Increase of current density, decrease of free cyanide, reduction of phosphates or lowering the bath temperature increases the red color. Green gold is produced by alloying with silver or cadmium. Deeper greens are produced by adding small amounts of lead acetate or arsenious oxide to the bath.

Antique gold finishes require special pretreatments to produce the desired effects. White gold is made by alloying with nickel. Colored gold plate can also be produced by depositing separate layers of gold over silver or copper and diffusing the metals by heat treatment. Purple gold can be made by depositing aluminum on gold and then heat treating in a reducing atmosphere.

The order of whiteness of the light colored precious metals runs as follows: Silver, rhodium, platinum and palladium. Rhodium makes an excellent finish over nickel. Platinum-gray colors are produced from alcoholic solutions of platinum salts, which form colloidal deposits leading to the gray color. Colors other than white are possible with silver finishes by treatment with sulphides. Green silver finishes are also possible but these are poorly adherent.

Owing to the variety of finishes possible on copper and the lack of any standardization of colors, adequate fulfillment of customers' orders is sometimes difficult. Brown finishes on copper are produced by baths of the sulphide of such metals as

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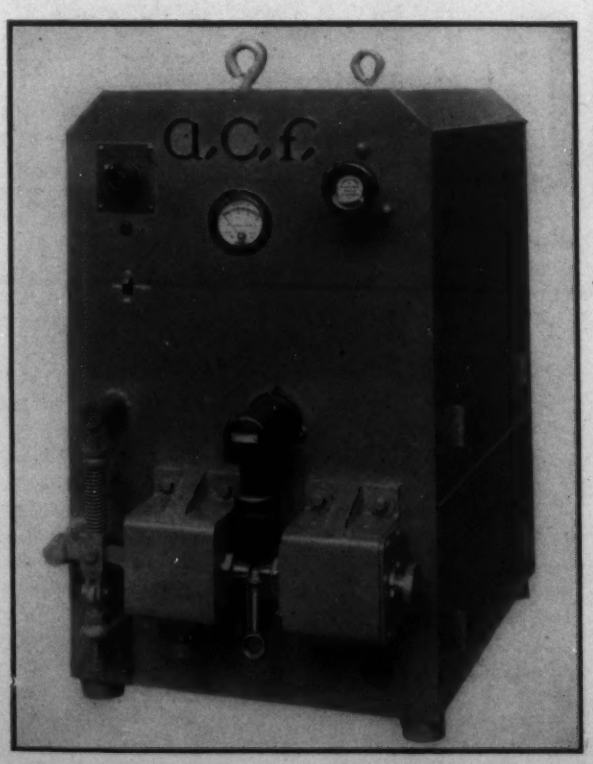

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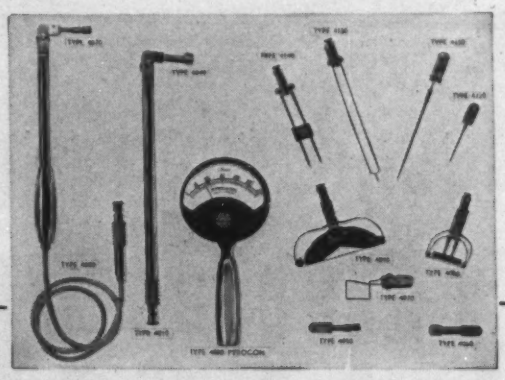

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potassium, antimony, calcium and barium. A brown, known as French bronze, can also be produced in a copper sulphate and sodium hydroxide solution. Odd shades of brown can be produced by a cathodic treatment in a bath containing potassium bromide and sulphuric acid.

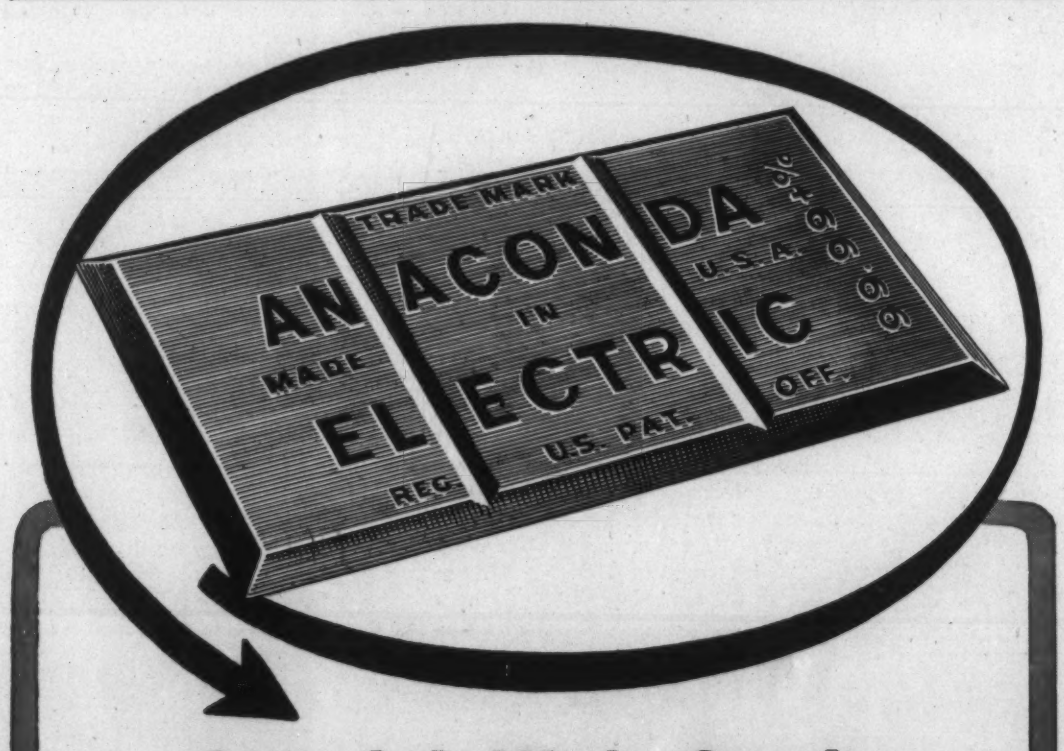
Patina cannot be reproduced exactly, but the color can be simulated by a dip bath containing hydrochloric acid, basic copper acetate, copper carbonate, powdered arsenic and ammonium chloride. "Royal Red" or "King's Red" is produced by heat treatment or a dip in molten sodium nitrate. To heat treat, use a preliminary lead plating, heat to a medium red and then buff off the dense black oxide coat to the red oxide underneath. Solutions of copper lactate are used to produce electrolytic coatings having beautiful interference colors.

Brass is more difficult to color than copper because of the impurities likely to be present. The cleaning and pretreatment must be considered more carefully to avoid changing the base color by either whitening the brass through solution of the copper or reddening it by dissolving out the zinc. Formulas are given to produce golden yellows, browns and bronzes, greens, blues, blacks and grays. The brown and bronze colors depend on the production of either a sulphide or an oxide coat. Some of the greens that can be produced are light-sensitive and change to black on exposure. Gray is produced by arsenic dips.

The coloring of iron and steel is of great industrial importance. Since iron is rather high in the electromotive series, it combines rapidly with other elements, offering many color possibilities. Unfortunately, many of these are soluble or decompose or do not provide adequate protection against rust. As a result, many finishes are protective rather than decorative. Colors can be produced by heat treatment, chemical dips below 200° F., molten salt dips or electrochemical treatments.

The well known temper colors will give a variety of colors by proper control of time and temperature. Only the blues and blacks are stable, however. The others must be protected by lacquer or varnish. Blackening can be produced with a selenious acid dip or a sodium thiosulfate plus lead acetate dip. Gunmetal or gray finishes are obtained with chloride dips. Brown colors are the result of artificial rusting of the steel, and must be protected from further oxidation. The use of molten nitrates is a satisfactory way to obtain gunmetal and other types of blue.

Iron can also be colored by copper-plating and then coloring the copper with one of the numerous copper coloring methods. Stainless steels are difficult to color, although several patented processes are in use. One of the latest produces a black finish on stainless steel. PCR (2)



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2a. Ferrous

Painting and Paints

A Composite

In his never-ending battle against corrosion, the metallurgical engineer has several resources available—use an alloy that resists the type of corrosion encountered, apply a protective coating, modify the corroding or contact conditions, etc. One phase of the second of these, the application of a paint or varnish coating, is not only the most common weapon and one of the most important, but when properly accomplished is an engineering operation as well.

Differences among metals with respect to basic corrosion behavior, surface qualities affecting coating adherence, reactions with individual coating ingredients, and pretreatments required, as well as differences in the performance of various finishes available for any one metal are factors that complicate the situation. Many of these are discussed in the group of articles abstracted herewith.

Pretreatment

Since no paint is absolutely impermeable, the metal should have a good surface before it is painted. According to M. CAILLAUX ("La Preparation des Supports avant Peinture," *Tech. Moderne*, Vol. 31, Dec. 1/15, 1939, pp. 687-691) the adherence of the paint depends on the nature of the metal, type and cleanness of the surface and the difference in coefficient of expansion between the coating and the metal.

Phosphatizing of iron and steel is growing in use for surface preparation; the so-called rapid treatment is more popular for this purpose than the slow method. The latter, which produces a finer-crystal coating, is better for exposure in the unpainted state. Phosphatizing is also applied to aluminum alloys and to other industrial metals.

One of these for which phosphatizing is reported to be highly successful as a pretreatment is zinc or zinc-coated metal. H. E. VAN SICKLEN of Western Electric Co. ("Better Adherence," *Steel*, Vol. 105, Nov. 20, 1939, pp. 66, 68-69) points out that organic finishes on zinc and zinc-coated surfaces lose adherence comparatively rapidly. Roughening alone does not significantly improve this. On the other hand, complete cleansing of the surface, followed by phosphate treating does result in satisfactory adherence.

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Mandrel-adherence tests on galvanized iron showed that phosphatizing this material offers an excellent surface for paint adherence. Finishes applied over surfaces pretreated in copper sulphate, various acids, alkaline permanganate or copper sulphate-ammonia-cyanide retained good adherence for a short period of time but soon lost it entirely; phosphate-treated surfaces were excellent, however, and provided satisfactorily extended paint adherence.

The order of adherence of several different finishes to phosphated zinc surfaces was about the same as to cleaned steel. Baked synthetic enamel is classed as the most desirable finish for use over phosphated zinc surfaces, although pigmented lacquers are almost as adherent, in point of time.

Often it is necessary to remove a coating of old lacquer before applying a new surface. FREITAG ("Abbeizmittel für Lackschichten," *Oberflächentech*, Vol. 16, Dec 19, 1939, p. 222) discusses removing agents for such coatings, and recommends a new agent—methylene chloride—containing dissolved paraffine (to retard evaporation) and a thickener, such as alcoholic methyl cellulose. Its advantages are non-flammability, good adherence even on vertical faces and quick softening action.

Rust-Inhibiting Paints

In painting steel, the work should be painted immediately after descaling, or, if not practicable, a panel wash applied to the slightly rusty surface as soon as possible, says J. C. HUDSON ("Protection of Iron and Steel Against Corrosion," *Iron & Steel*, Vol. 13, No. 5, Feb. 1940, pp. 158-159). The use of a rust-inhibiting primer such as red lead is essential. Red oxide of iron paints were the best of several finishing paints tested for durability.

However, for painting ships it is considered preferable to use a non-inhibitive primer, on the basis that the concentration of attack in seawater over a bare area will be more pronounced when the remainder of the surface is coated with an inhibitive paint. It is alleged that existing marine compositions furnish efficient protection against seawater corrosion. At any event, ships should be painted at 6-7 month intervals.

Other inhibitive pigments said to exert a passivating effect on iron, in addition to red lead, are iron oxide and ammonia-charged active carbon, according to tests by P. PRILL & E. BÖHM ("Versuch zum Nachweis der passivierenden wirkung einer mit Ammoniak beladenen Aktivkohle," *Korrosion u. Metallschutz*, Vol. 16, Mar. 1940, pp. 86-88). Paints possessing the last as an essential constituent of the pigment provide excellent corrosion protection. [Also, ammonia-charged carbon is a domestic German product, whereas red lead must be imported.—Ha]

Some Special Considerations

Domestic supply considerations are likewise involved in German attempts to develop drying compounds to replace linseed oil or tung oil, the conventional drying oils for paints and varnishes. The corrosion-prohibiting value of several such oil-free driers is examined by H. HEBBERLING ("Können ölfreie Bindemittel Korrosions verhütend wirken?" *Oberflächentech.*, Vol. 17, Feb. 6, 1940, pp. 17-18). Most of these substitute driers are alkyd or phenolic resins, and since they have a higher acidity than linseed oil, might result in ultimate attack on the underlying iron.

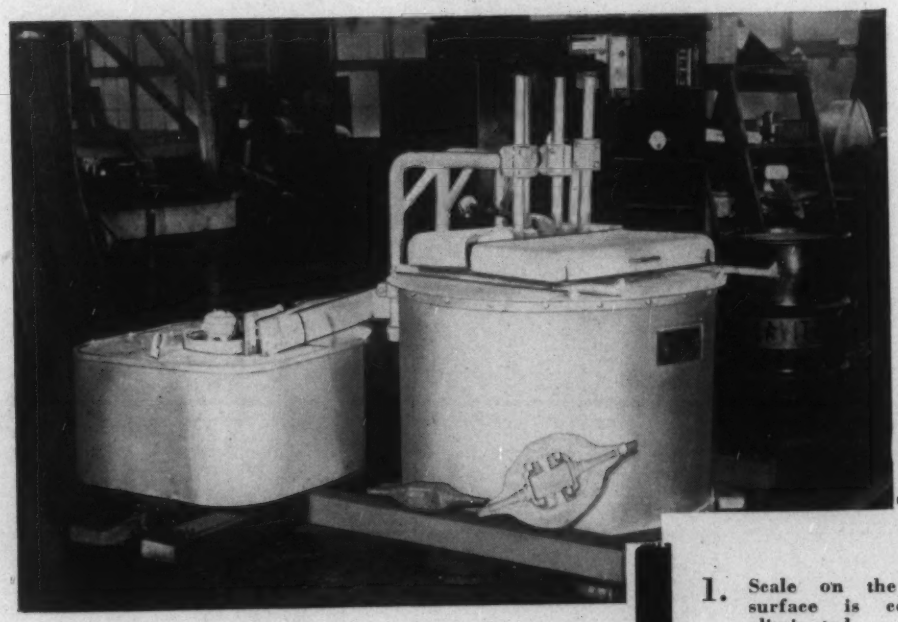
The suggested corrective, if such driers are to be used, is to employ them only in conjunction with alkaline pigments like white lead or zinc oxide. [Ought to go well, too, with Prill & Böhm's ammonia-charged activated carbon pigment mentioned above. An added advantage of this particular combination is its utility as an ingredient of the gray tones met so frequently these days on the well-turned-out European ship.—F.P.P.]

The problem of getting ships painted in a hurry was not unconnected with Mayne's attempts (described as possibly successful) to find a rust-inhibiting priming paint suitable for application to steel wet with water, mentioned by U. R. EVANS ("Report on Corrosion Research Work at Cambridge University Interrupted by the Outbreak of War," *J. Iron Steel Inst.*, Adv. Copy, May 1940, 16 pp.). Another objective of recent British research is a rust-inhibiting primer that can be applied directly to steel that has been partly weathered and whose surface therefore carries rust, iron salts, broken scale, etc.

An American product of this type, specially developed for direct application to rusty steel, is described by R. W. BAKER of Flood Co. ("Rust Problems," *Steel*, Vol. 107, July 1, 1940, pp. 62-64). Known as Penetrol, it is a clear primer that utilizes the rust as a protective pigment and stops further rusting, it is claimed. The primer is a blend of natural oils that penetrates to all the pores and interstices of the rusted steel, and also hardens into an elastic film from the bottom up without the aid of driers.

Paint films on iron and steel owe their protective ability to the "transition zone" between paint and metal more than to the paint itself, reports J. K. WIRTH ("Ueber

In Heating for Forging



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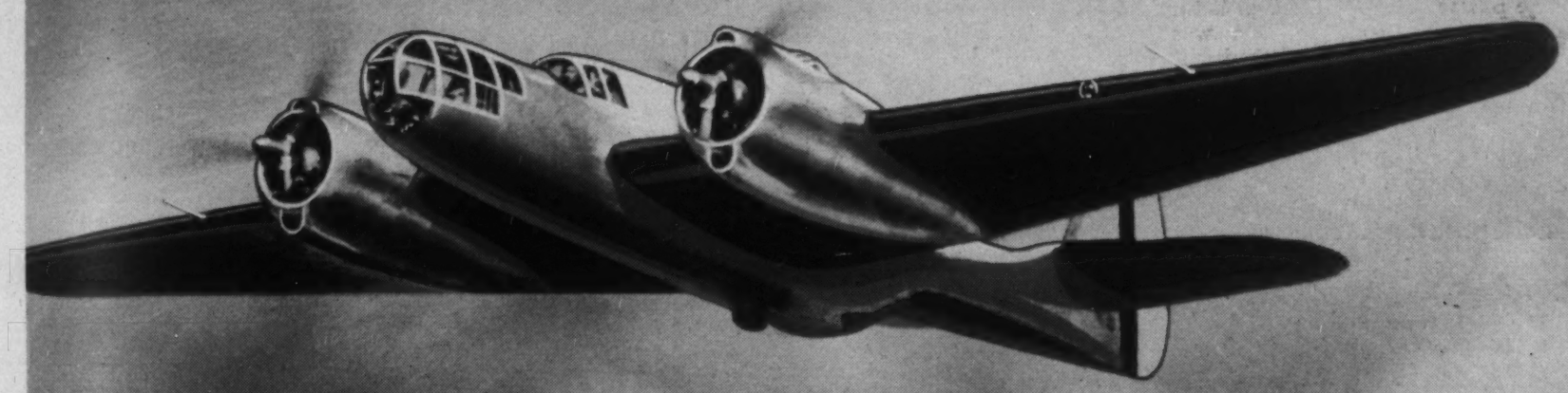

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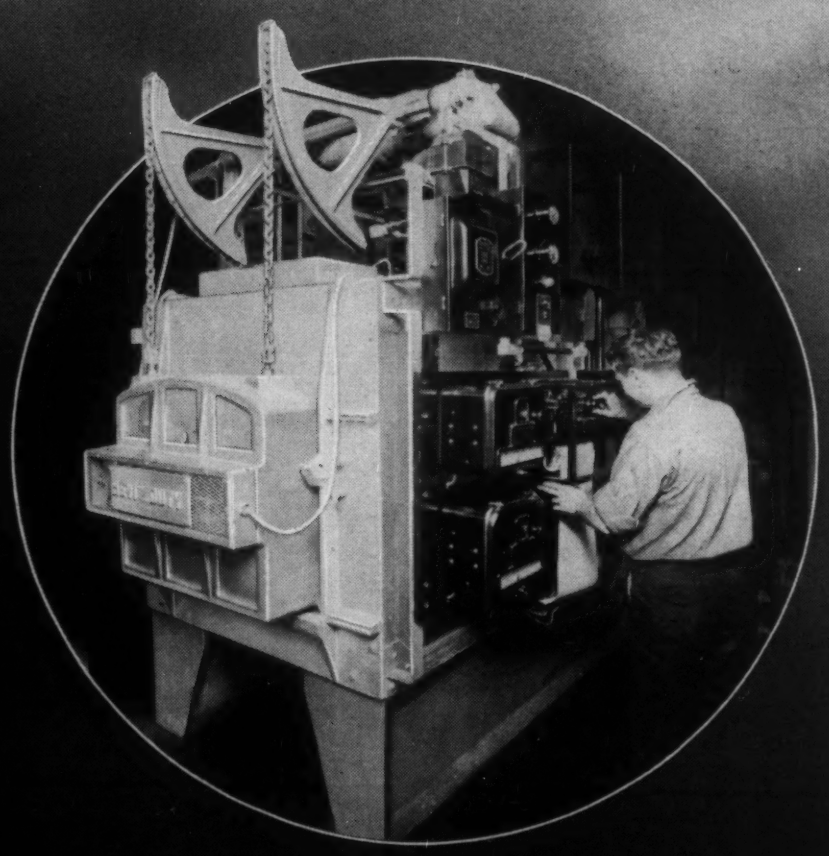

An HD-248418 Box Furnace—one of four similar Hevi Duty Furnaces at the Glenn L. Martin Co., Baltimore Md.

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die Korrosion unter Schutzfilmen," *Korrosion u. Metallschutz*, Vol. 16, Mar. 1940, pp. 69-76). Special tests in which the protective effect was measured for the paint film on the iron and then for the film alone showed clearly that corrosion protection must be due to a boundary layer between the metal and film, which prevents migration of hydrogen ions from the attacking medium to form local elements on the metal.

The passage of ions through a firmly adhering coat of paint on iron was much lower than through an otherwise identical coat of paint on a cellophane base (which offers no resistance to ion passage). The function of the paint itself is therefore chiefly one of protecting the boundary area from injury. X (2a)

Grain Size and Heat Treatment of Steel

A Composite

It has long been known that heats of sound steel of similar analysis may differ in their response to heat treatment and in their properties to a degree not explainable by differences in nominal chemical composition. Once mysterious, these differences lately have been successfully correlated with differences in the grain size of the steel at hot-working and heat-treating temperatures.

For engineers, designers and other users of steel, J. R. VILELLA of U. S. Steel Corp. ("The Grain Size of Steel—an Introduction to the Subject," *Mech. Engineering*, Vol. 67, Apr. 1940, pp. 293-307) offers a clear and useful exposition of the metallurgist's knowledge of the subject of grain size of steel. A review of carbon steel metallography is followed by a careful summary of information on grain systems, coarse- and fine-grained steels, cooling rates and grain size, methods of determining grain size, normality and abnormality, etc.

Regardless of grain size at room temperatures, when steel is heated above its transformation temperature, the newly formed austenite grains are initially small. During heating within the stable austenite range, the higher the temperature and the longer the time at that temperature, the larger the austenite grains tend to become. The size attained by the austenite grains at the maximum temperature is not altered by variation in the rate of cooling from that temperature under ordinary conditions.

In some steels, however, grain growth begins as soon as austenite appears while in others no growth takes place until the austenite is heated several hundred degrees higher. The former are usually called coarse-grained, the latter fine-grained steels. A fine-grained steel is thus *not immune, but resistant to* grain growth, and the term "inherent grain size" is clearly a misnomer.

Steels at room temperature are generally ferritic, but it is possible to detect at room temperature the austenite grain pattern that existed at the maximum temperature reached during the last heating in the austenite range. In the ferritic range, the tendency of the ferrite grains to grow with rising temperature is small, except after "critical deformation." The faster the cooling rate from the austenitic range, the smaller the ferrite grains. For the same cooling rate, the larger the austenite grains, the larger the ferrite grains.

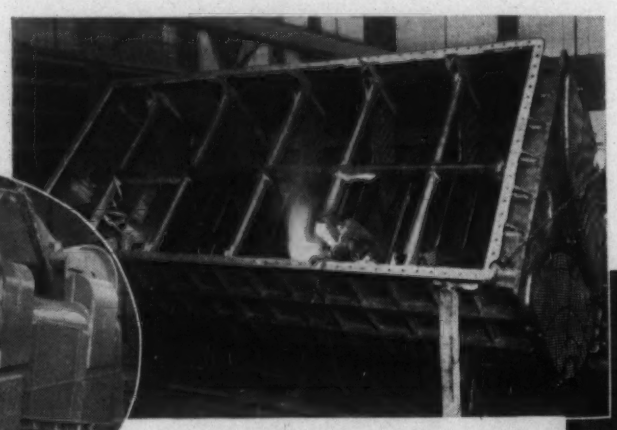
Austenite grain size measuring methods can be divided into (a) those that change the chemical composition of the metal in marking out the austenite grain boundaries, and (b) those based on the fact that under appropriate conditions of cooling, the austenite grains on transforming leave behind "foot prints" which disclose their size.

Among the first type is the widely-used McQuaid-Ehn test, which can be used without ambiguity only when the user understands that he is determining the austenite grain size developed only at one specific temperature and time and under the carburizing conditions imposed. In the second type of test, although the solid-solution austenite no longer exists as such in plain carbon steels at room temperature, the grain pattern established while the steel was austenitic is very often observable under the microscope.

So called coarse-grained steels have higher hardenability (are deeper hardening), higher tensile strength, lower ductility, lower impact strength, lower transformation temperature, more frequent quenching cracks and grinding cracks, and greater distortion in heat treating. The depth-hardening properties are directly related to the rate at which austenite transforms to ferrite and carbide. Fine-grained steels are shallower-hardening because they transform at a faster rate, *i.e.* in quenching a piece a larger proportion of the cross-section transforms to ultimately soft pearlite at high temperatures rather than to hard martensite at low.

The relation between grain size and properties is also examined by A. LEGAT ("Beitrag zur Frage der Zusammenhänge zwischen Korngrosse und Stahleigenschaften," *Berg.-u. Hüttenmänn. Monatsh. montan. Hochschule Leoben*, Vol. 88, Mar. 1940, pp. 29-35). He believes the properties of a steel can be related to its grain size only within certain limits. Of perhaps equal importance is the "state of the nu-

35 cu. yd. Man-Ten steel dipper welded with Murex Carbon-Moly by Marion Steam Shovel Co. Marion, O.



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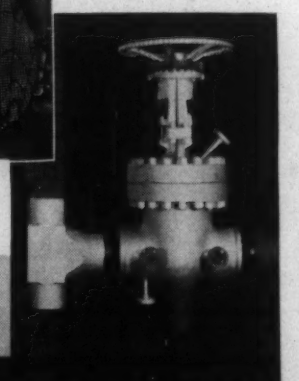

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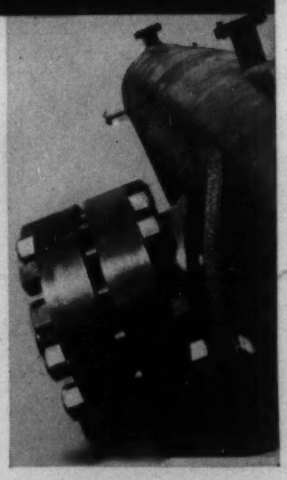

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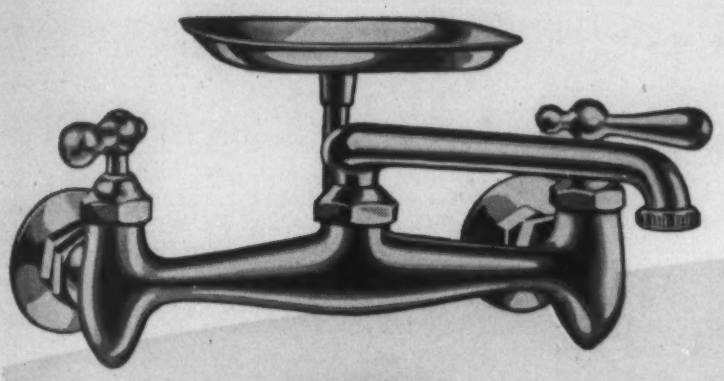

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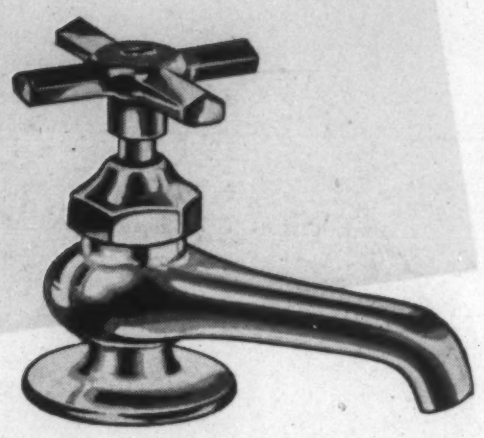

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clei" in the steel. If fine-grained steels are heat treated so as to dissolve the nuclei without coarsening the grain, the characteristic properties of coarse-grained steels will nevertheless result. X (2a)

Welding Construction Machinery

"Designing Construction Machinery for Production by Welding." H. C. Hettelsater (Harnischfeger Corp.) *Welding J., N. Y.*, Vol. 19, Apr. 1940, pp. 257-262. Practical.

Construction machinery builders have made rapid strides in the introduction of arc welding as a production method during the last five years, with consequent marked reduction in weight and in production costs. Cost reductions were often large enough to enable selling prices to be reduced to a point where completely new markets were opened up. Also, the welded machine with its lighter weight could be transported on light-weight trailers on secondary roads where the load-carrying capacity of bridges was too low to permit transportation of the older and heavier machines.

There has been a general adoption of the low-alloy structural steels for use in the structural parts of excavators. These steels are also used in booms, dippers, dipper handles and dragline buckets. For shovel booms and dipper handles the principal requirements are that the steels have high yield point, high ductility and resistance to shock, and that they are readily weldable. Mild steel has a very definite place in this type of equipment and is very commonly used in the main upper revolving frame of the machines and also in the lower structures. The use of high strength alloy steel welding electrodes for welding all parts made from alloy steels is recommended.

Tests were recently conducted to determine whether or not an alloy steel tube boom could carry heavier loads than a carbon steel boom built with the same size of sections. It was found that the safe load that could be carried on the alloy steel boom was practically in direct proportion to the yield point of the material used. The alloy steel tubing boom stood a 45% higher load than the carbon steel boom.

The principle of combining as many parts as possible into one unit with welding has been responsible for some of the greatest savings realized by arc welding excavating machines. Lap joints should be avoided if possible since they usually result in eccentric loading on the weld and also in excess metal being used. CEJ (2a)

Pack Carburizing

"Case Carburization of Steel." E. G. Mahin (Univ. Notre Dame) *Iron Age*, Vol. 145, May 30, 1940, pp. 17-22; June 6, 1940, pp. 53-57. Review.

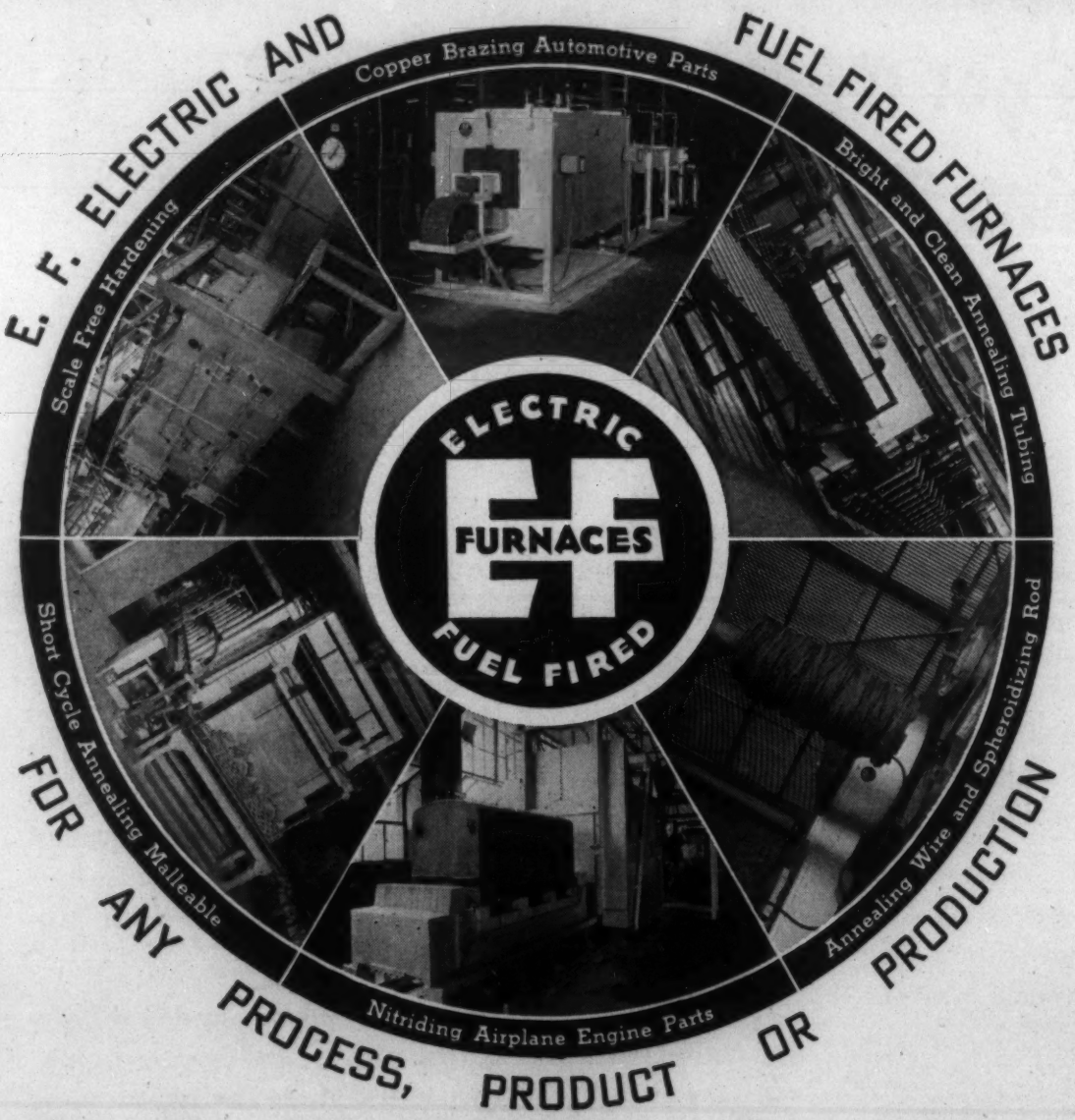
In pack carburizing, the surface of low-carbon steel is converted into high-carbon steel by packing in a metal container and surrounding with a carbon-containing granular material. The whole is brought to the desired temperature and held there until a case of predetermined depth is obtained.

The oxygen in the surrounding air and the carbon present form carbon dioxide and carbon monoxide; the latter is assumed to be the active carburizing agent. This dissolves in the surface layer and decomposes to leave elemental carbon dissolved in the austenite, and the carbon diffuses inward. The reactions are practically continuous if there is a high initial concentration of carbon monoxide; the air enclosed by the carburizer usually supplies enough oxygen. Correct porosity and suitable energizing of the compound are important.

The depth of case is determined from the required mass strength of case and the amount of wear to be expected, and may be anywhere between a few thousandths of an inch to $\frac{1}{8}$ in. or more. In commercial practice time at full carburizing temperature may be 1-20 hrs. Box-cooled steel must be heated into the austenitic temperature range before quenching, so that all pearlite is converted into austenite and so that the austenite may reabsorb any primary cementite. The hypereutectoid outer zone should be limited to as small a depth as possible.

A steep carbon gradient may result from improper balance of rate of carbon absorption and rate of carbon migration. If a slow carburizer is used at high temperature, the migration of carbon inward keeps proper pace with its absorption, and a deep case can be obtained without excessive carbon at the surface. At a given temperature, variation in the speed of carbon absorption is governed by the type of carbon selected for the carburizer base and by the kind and quantity of energizer used. An admixture of certain ferroalloys has been found to slow carburizing action.

If a hypereutectoid composition is near the surface, a slowly-cooled piece would show hypereutectoid and hypoeutectoid zones adjoining, with no eutectoid zone of appreciable width between. This variation in carbon content from surface to core results in a high austenizing temperature (A_3) at the high-carbon surface zone; A_3 drops to the lowest value where the narrow eutectoid zone exists, and rises again towards the core. VSP (2a)



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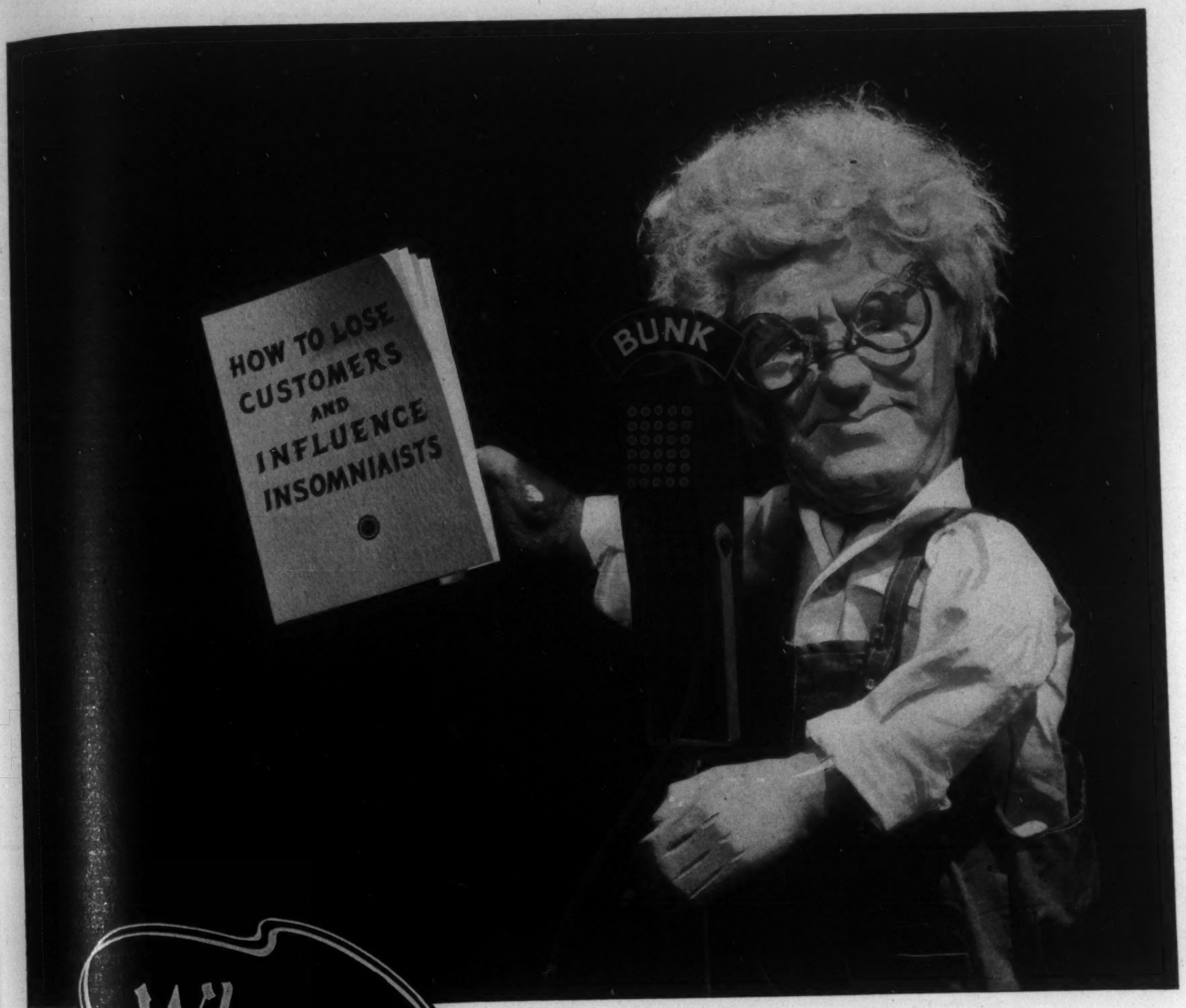

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Flame-Cutting Steels

METALLURGICAL INVESTIGATION OF FLAME-CUTTING ("Contribution a l'Étude Metallurgique de l'Oxy-coupage") D. SÉFÉRIAN. *Rev. Soudure Autogene*, Vol. 31, Oct. 1939, pp. 788-792. Original research.

Temperature distribution during flame-cutting was measured with thermocouples located at certain distances from the cutting line. The heat is more concentrated in the case of flame cutting than in arc welding, and much more so than in the case of gas welding. The temperature gradients are greater for the cutting process than for the welding processes, and the cooling rate also is higher.

This means that the transformation zones in the metal are narrower than in the case of welding. Thus, a more pronounced hardening effect and higher internal stresses may be expected. A micrograph for mild steel with 0.15% C shows that the transformation zone is about 0.43 in. deep; about half-way through, this zone presents a coarse pearlitic structure, and then becomes a combination of pearlitic in a ferrite matrix of normal grains. In an alloy steel, the transformation zone extended to a depth of 0.51 in. About ⅓ of this was troostite with some martensite needles, and the remainder was coarse-grained and sorbitic.

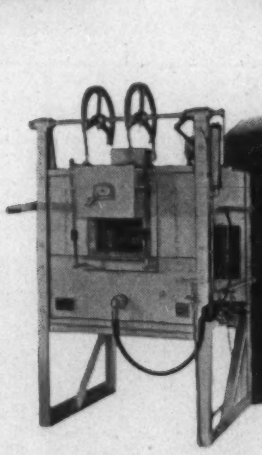
The chemical analysis has an influence on the structural changes and on the cutting process itself. In low-carbon steel (0.03% C), no change in structure takes place, except that near the cutting surface over-heating is evident through slight grain growth. Another phenomenon observed in this steel was a carbon enrichment near the edge, apparently produced by loss in iron. This is in contrast to higher-carbon steels, in which generally decarburization is produced by the action of oxygen.

In a 0.13% C steel, the cut surface is sorbitic (in a ferrite matrix). The structure of the cut surface of a special steel (0.20% C, 0.57 Cu, 0.52 Cr) is troostitic, showing greater hardness along the cutting line but without brittleness. In a steel of the 0.42% C, 0.42 Cr and 0.75 Mn type, an austenite-martensitic structure was observed on the border, then within 0.08 in. a troostite-sorbite structure was found.

As to the influence on cutting quality, silicon has a detrimental effect as it favors the precipitation of carbon in the form of graphite, whereas manganese, which facilitates the solution of carbon, is desirable up to 6%. Phosphorus is without influence up to 1 or 2%. Pearlitic nickel-steels are easily cut, austenitic nickel-steels become more difficult with increasing carbon content. High-nickel steel (35%) even with low-carbon content cannot be cut. Chromium under 2% is not detrimental, but with higher chromium contents difficulties increase; a higher cutting temperature and eventually preheating are necessary. Steels with more than 13% Cr cannot be flame-cut.

Molybdenum in concentrations of more than 5% renders the flame-cutting operation very difficult. Tungsten steels (under 10% W) are easily cut, but over 15% W makes cutting impossible. Vanadium behaves in a similar manner as to molybdenum. Copper is without effect up to the limit of solubility. RPS (2a)

Fact



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Heat Treating Light Alloy Castings

"HEAT TREATMENT OF LIGHT ALLOY CASTINGS." H. G. WARRINGTON. *Foundry Trade J.*, Vol. 62, May 16, 1940, pp. 359-360; May 23, 1940, pp. 385-388. Practical review.

The sensitivity of an aluminum alloy or magnesium alloy casting to quenching stresses, distortion and cracking will increase with the size and complexity of the casting. The presence of quenching stresses cannot be tolerated on castings such as engine cylinder blocks or heads, owing to the intricacy of the machining and the temperature variations in service; the latter may relieve the residual stresses and thus cause distortion, throwing bolt and stud holes out of alignment and causing ovality of bores.

After solidification of the liquid metal in the original casting operation, it passes through the same temperature range as that employed for the usual solution treatment. As cooling in the mold is never slow enough to obtain equilibrium conditions, there is a certain retention of solid solution, and subsequent precipitation treatment will improve the mechanical properties. At the same time, a stabilizing effect is obtained through the reduction of casting stresses.

Consideration of the heat treatment effects is of assistance in choosing an alloy for operation at elevated temperatures. The whole question of the heat treatment of castings for high-temperature service is still controversial. If a component such as a piston or cylinder head is likely to be "annealed" by temperatures reached in service, it is useless to heat treat it at all. A corollary practice is to heat treat the component, and then to anneal it at its maximum operating temperature.

Rapid quenching in cold water of a large casting induces variation in the rate of cooling that will cause quenching cracks,

visible distortion and residual stresses. Under certain conditions, with a boiling water quench, a protective cushion of steam forms around the component until its temperature has been reduced to something approaching the boiling point of water.

The most dangerous feature associated with heat treatment is overheating. Its effects are first seen in evidences of excessive distortion, accompanied by cracking or blistering. Fusion of the eutectic constituents weakens the casting intrinsically and renders the material extremely brittle. The failure of a casting to respond to heat treatment and show the expected increase in tensile properties is elusive in origin, and may be caused by casting defects.

For the solution treatment of magnesium-base alloys, atmospheric control is necessary; an ideal practice is to use oil or gas fuel in a fully recirculating furnace. Nitrate or other salt baths also provide low-initial-cost, easily controlled and satisfactory heating for aluminum alloy castings. AIK (2b)

Anodizing Aluminum

A Composite

Several processes are in commercial use for producing a protective oxide film on aluminum and its alloys by anodic treatment. The coatings so produced not only improve the corrosion resistance of the aluminum, but enhance its abrasion resistance as well. They are fairly good electrical insulators, and provide aesthetic appeal when desired through their amenability to integral coloring or dyeing. Types of coatings, methods of producing them, operating details, and dyeing technique are among the topics covered in several recent articles.

Available Methods

A practical review of the various methods available is given by "ANODIZER" ("Anodizing of Aluminum," *Machinery, London*, Vol. 55, Nov. 9, 1939, pp. 137-143). The ordinary air oxide is 0.00001 in. thick; the electrolytic oxide may be over 0.008 in. thick. Electrolytic methods may use chromic, sulphuric or oxalic acid solutions.

Bengough uses an electrolyte with over 2.5% chromic acid, under 0.02% chlorides, and under 0.05% sulphates; current density, temperature (about 100° F.), and electrolyte purity must be controlled carefully. About 1 hr. and 0.15-0.20 kw.-hr./ft.^{2} are required.

The various processes using sulphuric acid are generally grouped under the name Alumilite and probably are the most popular. The electrolytes commonly are 12-20% or 60-77% by wt. of sulphuric acid with additions of various retarding agents, organic materials, and inorganic salts. The Sheppard process adds ethyl alcohol or glycol to 3% sulphuric acid; Alumilite adds ammonium sulphate and retarders such as glycerine to 15-20% or 60-70% sulphuric acid; Tennants adds 15% by volume of glycerine to 65% by volume of sulphuric acid; and Anotint uses 33% sulphuric acid plus carbohydrates, glycerine, or metals.

In the sulphuric processes, cooling must often be used to keep the temperature around room temperature. Time varies from under 30 to 45 min.; current density from 5 to 10 amps./ft.^{2}; d.c. voltage from 10 to 30 v. A.c. alone gives softer films than d.c., but when superimposed on d.c. gives harder and more compact films. Energy consumption of 0.05-0.22 kw.-hr./ft.^{2} is used. The main difficulty is maintaining the composition of the electrolyte constant.

The chief oxalic acid process is the Eloxal, used in Germany and Japan. The oxalic acid content is 3-10% with optional additions of oxalates, chromates, colloids and organic substances; the temperatures are 60°-90° F. Up to 100 v. and 45 amps./ft.^{2} may be used. Time required is only 10-45 min., but the kw.-hr./ft.^{2} values are high (0.4-1.0). Superimposed a.c. is often used to give harder films.

The great variety of surface qualities available by using the oxalic acid (Eloxal) process and the production factors involved are exhaustively discussed by H. RÖHRIG ("Beschaffenheit anodisch erzeugter Oxydschichten auf Aluminiumlegierungen," *Z. Ver. deut. Ing.*, Vol. 84, Mar. 30, 1940, pp. 223-225). Whereas sulphuric-process anodic films are invariably colorless, a.c. oxalic-process oxides may range from light yellow to dark bronze, according to the thickness and alloying agents present.

Otherwise colorless layers become golden if copper be present; magnesium silicide produces a milky-blue tint, manganese brown and chromium yellow. Alloys to be heat treated and anodized should not contain over 3% Mg or 3% Si if spottiness

Anodizing Difficulties

Fault	Cause	Remedy
Iridescence	thin film	check contacts, temperature, time, amps.
Discoloration with pitting, usually at weld	nonuniform structure	heat treatment of weld or use of a.c. H_2SO_4 process
Occasional pitting	inclusions	examine for surface or internal inclusions
General pitting	contaminated solution	check solution analysis
Brown stains	chromic acid oozing out of pores or cracks	thorough washing gives some improvement; improve quality of base metal
Reddish stains	rouge from polishing	change final polishing medium
Current density too high	foreign metal at anode, short circuits, temperature or voltage too high	check work set up, voltage; reduce temperature
Current density too low	temperature too low; solution old	check temperature; renew solution

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and opacity of the films are to be avoided.

Dyeing Anodic Films

Coloring of anodized layers, however, usually involves dyeing, and some beautifully and highly decorative finishes of this type have been available for some time. F. HILL ("Practical Notes on the Dyeing of Anodized Aluminium," *Light Metals*, July 1940, p. 172) covers the essentials of the dyeing technique and evaluates over 35 individual dyes for use in the chromic acid or sulphuric acid processes.

Freshly anodized material should never be handled with the bare hands, as even the smallest amount of grease on the film will act as a resist and give patchy coloring. Similarly, oil or grease in or on the electrolyte is very harmful.

All water-soluble dyestuffs will dye or stain anodic films, but not all are equally satisfactory. Alizarine Cyanine RR, Solochrome Orange GRS, Solochrome Orange MS, Alizarine Green S paste, Solway Green GS and Alizarine Red AS are "very good," and Solochrome Yellow WNS and Solochrome Red BS "excellent" from the standpoint of light-fastness.

Other dyestuffs that require a slight acidity (acetic) of dye solutions for their maximum light-fastness, but are then "very good" or "excellent" are Lissamine Fast Red BS, Lissamine Fast Yellow 2GS, Solway Blue SES, Solway Blue AS, Solway Blue BS, Naphthol Green BNS, Naphthaline Blue RS and Nigrosine 2Y.

The dissolved dyestuff solution is added to the hot dye liquor, to which acetic acid is added if required. The freshly-anodized aluminum is now placed in the hot bath for 20 min., with agitation. Washing and drying complete the process when the desired color has been developed.

In the production of medium-strength shades, 1 lb. of dyestuff to 100 gals. of water is often used. Because certain metals and dyestuffs react with each other, relatively inert tank materials such as ceramic linings, rubber linings, Monel metal, stainless steel, etc., should be used.

Improving Quality

A useful basis for diagnosing anodizing troubles is given by "WORKS CHEMIST" ("Plant Layout and Operation for the Anodic Oxidation of Aluminum and its Alloys," *Sheet Metal Inds.*, Vol. 14, Feb. 1940, pp. 133-135) and is summarized in the table (p. 205). Among the trends noted is one towards the use of continuous anodizing, particularly with sulphuric acid. With oxalic acid the use of a spray with the nozzle as cathode has been successful in treating long lengths of strip, wire or tubes.

Anodically-treated aluminum of 99.8% purity or better makes a better reflector than chromium plate if certain precautions are followed, say A. G. C. GWYER & N. D. PULLEN ("Aluminium Reflectors," *Metallurgia*, Vol. 21, Dec. 1939, pp. 57-60). Reflectivity measurements of anodically treated aluminum (Brytal process) reflectors indicated that a minimum in reflectivity occurred at 3μ. Maximum absorption by water also occurs at this wave length. In the Brytal process the article is boiled in water after anodic treatment and then waxed. It was found that the low reflectivity at 3μ could be avoided by not boiling, and, instead, heating to about 400° F. and then waxing.

It could also be avoided by heating in oil, in which case no waxing was necessary. The reflectivity at 3μ is important in reflectors used in electric heaters because the peak in the intensity of radiation at 1200° K. occurs near this wave length.

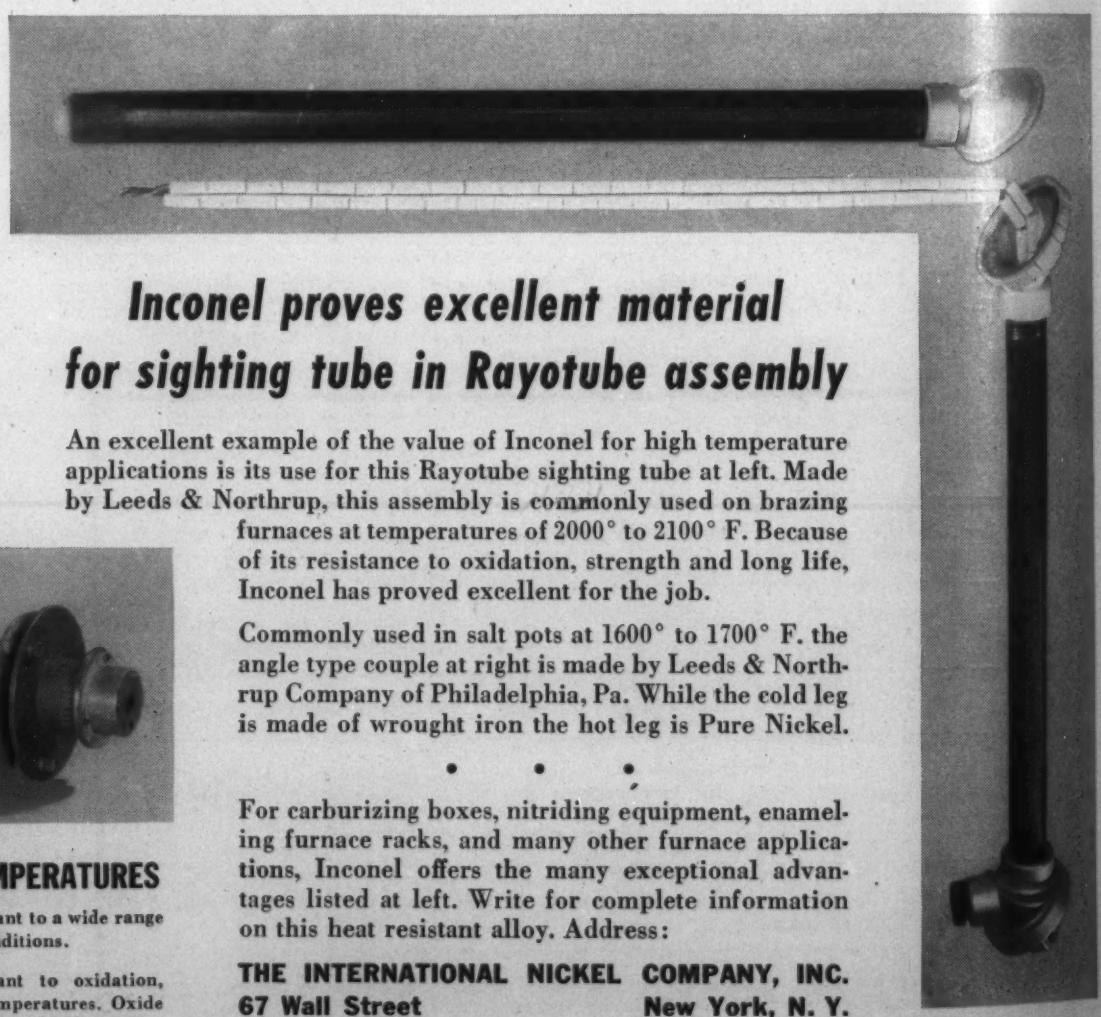
The Active Layer and pH

The dielectric properties of anodic films on aluminum, as related to the formation of the so-called "active layer," to the structure of the film and to operating conditions were studied by AKIRA MIYATA ("On the Residual Active Layer," *Sci. Papers Inst. Phys. Chem. Research, Tokyo*, Vol. 37, Jan. 1940, pp. 30-57; in English). The dielectric properties of the oxide film are affected by humidity if its pores are not sealed by a steam treatment. The dielectric constant of the dry oxide film on aluminum is about 8.

About 75-80% of the original active layer is retained in the d.c. (oxalic acid) film. The residual active layer of the a.c. film has a very irregular surface. Electrolytes attack the active layer more severely when the work is cathode than when it is anode. What reacts with the active layer also attacks the oxide film itself and may be utilized to increase film porosity.

The effect of pH of the electrolyte on the stability of this active layer, and therefore the behavior of *alkaline* anodizing baths, were also investigated by MIYATA ("The Hydrogen Ion Concentration in the Forming Solution of Anodic Aluminum," *Ibid.*, May 1940, pp. 232-273). In a simple boric acid solution, the film formation must await the solution of some aluminum in the electrolyte, after which a film of high breakdown value can be formed. In ammoniacal solutions, an unstable film, of low breakdown voltage, is produced. Long-time treatment in acid solutions gives a relatively thin but dense "waste layer," and in alkaline solutions a thick but porous waste layer. X (2b)

TUBES for the HEART of the FURNACE



Inconel proves excellent material for sighting tube in Rayotube assembly

An excellent example of the value of Inconel for high temperature applications is its use for this Rayotube sighting tube at left. Made by Leeds & Northrup, this assembly is commonly used on brazing furnaces at temperatures of 2000° to 2100° F. Because of its resistance to oxidation, strength and long life, Inconel has proved excellent for the job.

Commonly used in salt pots at 1600° to 1700° F. the angle type couple at right is made by Leeds & Northrup Company of Philadelphia, Pa. While the cold leg is made of wrought iron the hot leg is Pure Nickel.

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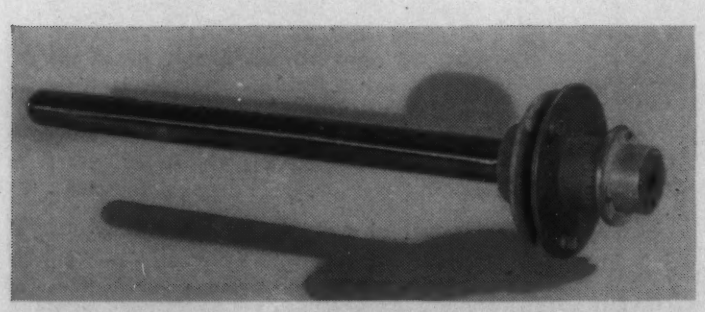

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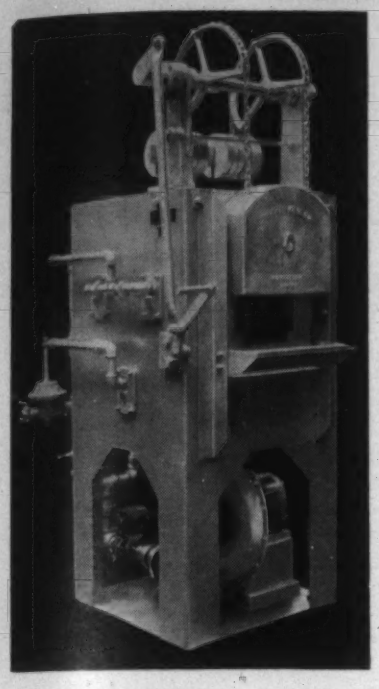

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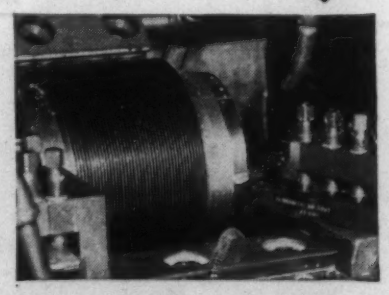

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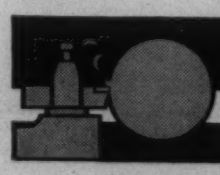

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3a. Ferrous

Protective Coatings Against Corrosion-Fatigue of Steel

A Composite

From the time of the earliest experiments on corrosion-fatigue by Haigh and McAdam until the present, it has become increasingly evident that the best defense against this type of structural damage is the prevention or retardation of its occurrence. Protective coatings seem, so far, to be the most promising form of protection. At the June meeting of the American Society for Testing Materials, two interesting papers were presented on this subject.

THOMAS J. DOLAN & HUGH H. BENNINGER of Univ. Illinois ("The Effect of Protective Coatings on the Corrosion-Fatigue Strength of Steel," *Am. Soc. Testing Materials*, Preprint No. 30, June 1940) reported on rotating-beam fatigue specimens of several grades of S.A.E. steel. JOHN N. KENYON of Columbia Univ. ("A Corrosion-Fatigue Test to Determine the Protective Qualities of Metallic Platings," *Am. Soc. Testing Materials*, Preprint No. 31, June 1940) made corrosion-fatigue tests on specimens of automobile bead wire used for automobile tire reinforcement. In the Kenyon paper preliminary static, physical and fatigue mechanical tests were made on the bead wire and were found inadequate for determining the resistance of bead wire with different coatings to corrosion-fatigue. The Dolan-Benninger paper assumed this inadequacy.

Test Conditions

Dolan and Benninger used rotating-beam fatigue machines giving cycles of 1450 complete reversal of stress per minute. Kenyon used a rotating-arc fatigue machine (see METALS AND ALLOYS, Vol. 6, Aug. 1935, p. MA 331 L 5) operating at 6,000 r.p.m. and setting up cycles of reversed flexure. Essentially the rotating-arc fatigue test uses a specimen bent automatically to the arc of a circle by means of two inclined babbitt metal guides, and from one end this wire is rotated about its axis by a motor.

The other end of the wire is left free to slide longitudinally in its guide and, in so doing, the test specimen automatically assumes the curvature of the circular arc. Some 15 in. of wire are thus subjected to equal stress reversals with fatigue failure occurring at the weakest point within this length. The rotating arc dips into an oil bath which dampens out vibrational effects. This dampening method offers a further advantage for making corrosion-fatigue tests wherein the oil bath is replaced by aqueous solutions.

Dolan and Benninger used a stream of tap water as the corroding agent. The total hardness of the water varied from 250 to 300 p.p.m., dissolved oxygen varied from 6 to 8 p.p.m., and the pH value ranged from 7.8 to 8.2. Water temperature was approximately 63° F.

Kenyon used distilled water for most of his tests, with a variation of pH value in one series of tests. He also used a 3% salt solution in tests of copper-zinc plated specimens. In Kenyon's tests the wire was rotated in a bath of the corroding liquid.

Corrosion-Fatigue of Coated Steels

Metal and Coating	Thickness of Coating in.	Ratio of Endurance Limit in Water to Endurance Limit in Air	Investigators
S.A.E. 3120, quenched-and-tempered	.....	.224	Dolan and Benninger
S.A.E. 3120, cadmium-plated	0.0001	.254	
S.A.E. 3120, zinc-plated	0.00015	.418	
S.A.E. 3120, cyanided	0.004	.238	
S.A.E. 6120, nitrided	0.02	.809	
S.A.E. 1020, silicon-impregnated	0.02	1.000	
Bead Wire, no coating	.....	.522	Kenyon
Bead Wire, bronze-plated (displacement)	.....	.352	
Bead Wire, bronze-plated (displacement)	.....	.471	
Bead Wire, Bronze-plated (electro lytic)	.....	.276	
Bead Wire, copper-zinc plated	.....	.520	
Bead Wire, copper-zinc plated	.....	.426	

Behavior of Coated Steels

The results of the tests are summarized in the Table. Kenyon noted that plating with a more noble metal, such as copper, may actually contribute to the embrittlement of steel wire due to the rapidity of galvanic action at pinhole points of imperfection in the plating. No embrittled condition was encountered in wire that had been galvanized before plating with copper.

Dolan and Benninger noted that specimens with a silicon impregnation case developed the same endurance limit when tested in air or in water, but the value obtained for this endurance limit was comparatively low (about 22,500 lbs./in.^{2}). Zinc-plated specimens had a greater corrosion-fatigue strength than the cadmium-plated specimens, but both platings were rather thin and gave endurance limits less than 45% of the fatigue strength of the uncoated steel in air. Specimens with a nitrided case proved very efficient in resisting pitting by corrosive attack, and a very high corrosion-fatigue strength was obtained for the nitrided specimens (85,000 lbs./in.^{2}, 80.9% of the value in air).

In addition to the results shown in the Table, Dolan and Benninger made a few tests on S.A.E. 3140 steel coated with Bakelite varnishes. The problem of adherence of varnish to unroughened specimens was somewhat troublesome, but there was some evidence of endurance limit of Bakelite varnish-coated specimens up to 60% of the endurance limit in air.

In general, the percentage reduction of fatigue strength due to corrosion-fatigue was less in Kenyon's tests than in those of Dolan and Benninger. This may be due to a combination of several factors. Kenyon reported endurance limits for 10,000,000 cycles, while Dolan and Benninger reported endurance limits for 100,000,000 cycles. Kenyon ran his tests at higher speeds than that used by Dolan and Benninger, thus the time under corrosion for any given number of cycles was smaller in Kenyon's tests. Kenyon ran his specimens in a bath of still water, while Dolan and Benninger used a stream of water flowing over the specimen. The corroding media used were not the same, but this seems to be a rather minor factor.

Kenyon's conclusion that plating with a more "noble" metal (such as copper) may actually contribute to the embrittlement of the steel is worthy of careful study. The high results obtained by Dolan and Benninger with nitrided steel and protection against corrosion-pitting by the silicon impregnation of steel are of special interest.

The test results tend to confirm the current idea that the protective value of a coating agent against corrosion-fatigue depends upon its resistance to cracking under cycles of repeated stress, and upon its freedom from pinholes or cracks in the coating in a state of nominal freedom from stress. HFM (3a)

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Alloys for Paper Mill Equipment

A Composite

It would be a wonderful thing for the paper industry (and for the stainless steel manufacturers, too) if stainless steel could be used wherever strong chemicals are handled in paper processing. But stainless is still too expensive for universal service, and some cheaper compromise that will provide an approach to satisfactory resistance must be employed in many cases. Two basic means of effecting such cost-durability compromises—the use of stainless-lined equipment, and the use of intermediate alloy steels—are described in recent articles.

Selection of a particular alloy to be used for lining processing equipment for a particular purpose should be based on very careful tests duplicating as closely as possible the conditions of fabrication and intended service, according to MERRILL A. SCHEIL of A. O. Smith Corp. ("Corrosion-Resisting Alloy-Lined Vessels in the Paper Industry," *Paper Trade J.*, Vol. 110, Apr. 18, 1940, pp. 36-42). The general practice is to avoid the use of materials that show a greater penetration rate than 0.005 in./yr.

Stainless Steel Linings

Where pitting attack has occurred, samples should be examined under a microscope (at least 40X) to determine ultimate penetration depth and to locate cracks or similar defects. The author and S. L. Hoyt have shown previously that certain austenitic stainless alloys are susceptible to stress-corrosion cracking. Investigations showed strain as well as elastic stress to be necessary for stress-corrosion cracks in 18/8 when it is in a susceptible structural condition.

Stress-corrosion cracking in austenitic alloys is intergranular in nature. Susceptibility to intergranular attack is not always sufficient to produce cracking, even though the steel is stressed and subjected to suitable corrosive conditions. At present, it appears that this variable behavior is due to some characteristic of the alloys in the as-received condition. Susceptibility to stress-corrosion cracking has been experienced in certain samples of type 304 (18 Cr, 8 Ni), type 316 (18 Cr, 12 Ni, 2.5 Mo), type 329 (25-30 Cr, 3-5 Ni, 1.5 Mo), nickel-molybdenum-iron, copper-nickel, nickel, and copper-silicon alloys.

An example of a recent corrosion-testing program is the case of a large lined storage tank that required field erection of the fabricated parts. The intended service was the storage of raw sulphite liquor at temperatures up to 180° F. and pressure of 25 lbs./in.^{2}, and which would allow for a higher concentration of sulphur dioxide than obtainable in wood storage tanks. The test results obtained from stress-corrosion specimens indicated that certain alloy types were satisfactory and that the fabrication treatments necessary to build the tank could be used. Lined test plates were made duplicating all the construction details and surface finish that might be used in the field-erected tank. These specimens were then subjected to over 1300 hrs. exposure under operating conditions.

The tests indicated that either 18/8 Cb or 18/8 Mo alloys would be satisfactory if properly handled. The lower cost 18/8 Cb alloy was selected. Inspection of the tank after several months' service showed no evidence of any corrosion of lining. The latter had been bottle-tight with no signs of leakage at the weep holes.

Intermediate Alloy Steels

The suitability of intermediate alloy steels for certain Kraft mill applications is investigated by C. H. MCCOLLAIN ("Alloy Steels and Kraft Corrosion," *Paper Mill*, Vol. 62, Nov. 4, 1939, pp. 14-19; abstracted in *Nickel Bulletin*, Vol. 13, June 1940, p. 130). Particular attention was paid to the effect of black liquor on steels used in evaporator tubes, liquor heaters, liquor lines, etc.

Since pitting is the result of electrochemical attack, potentiometric studies were made in black liquor using a number of ferrous and non-ferrous alloys. There was shown to be no reason to expect appreciable galvanic action in black liquor through combining mild steel with any of the alloy steels tested (nickel, nickel-molybdenum, chromium-molybdenum, nickel-chromium-molybdenum steels).

Extensive plant-operating surveys were also made, with results covering studies in 20 mills, ranging from small units to large-scale. In some cases, lots of 100 tubes each, of several different compositions, have been set up in the same evaporation body. Two alloy steel groups—chromium steels and nickel steels—modified by copper, molybdenum and silicon additions, were studied.

The conclusions drawn at this stage of the work are only tentative, but should be of interest none-the-less. The chromium steel types are showing the least encouraging results of the two classes. Among the nickel steels results are better; nickel contents of 3% or higher are decidedly beneficial for black liquor evaporator tubing. One mill reports that 3.5% Ni steel outlasted 5 sets of carbon steel tubes.

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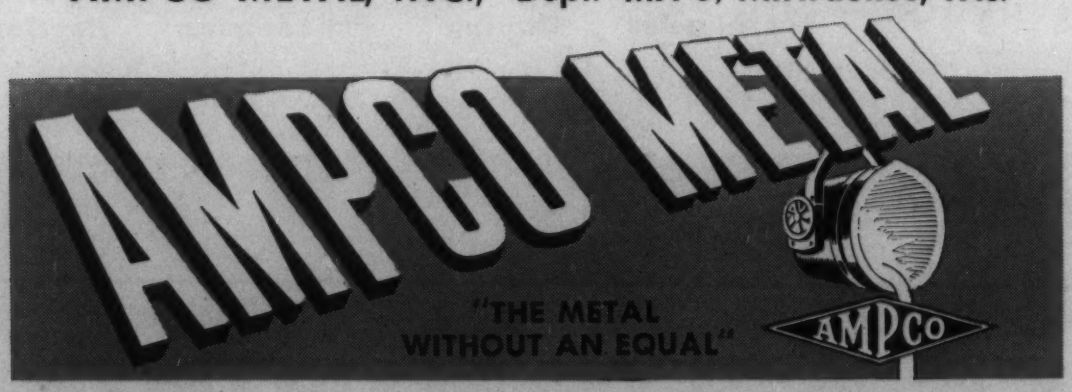

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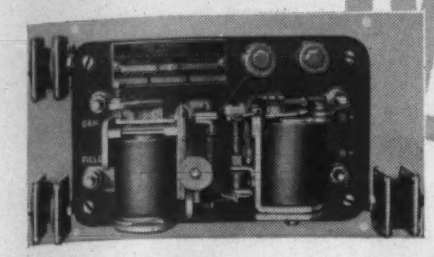

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It has been suggested that where failure occurs at the tube ends, the latter could be cut off and a more resistant material (stainless) could be applied as in the "safe-ending" of boiler tubes. This practice has not been uniformly successful in the refinery, and in black liquor the use of stainless steel in this way would certainly involve the risk of galvanic corrosion. X (3a)

Fatigue Strength of Welds

A Composite

One of the deterrents to the use of welding as a means of fabricating bridges has been the lack of knowledge of the fatigue strength of welded joints. Early European tests showed fatigue strengths of structural members joined by welding to be as low as 10,000-15,000 lbs./in.^{2} American engineers have waited for fatigue tests of welded joints on the largest possible scale before they could easily sanction fabrication by welding.

These have evidently been provided by W. M. Wilson & A. B. Wilder of Univ. of Illinois ("Fatigue Tests of Welded Joints in Structural Plates," *Welding J., N. Y.*, Vol. 19, Mar. 1940, pp. 1005-1085), using 50,000-lb. capacity machines specially designed for these tests. Loading was axial, with any tension-compression ratio desired available. Machine speeds were 180 r.p.m. The two steel plates tested contained 0.28 and 0.23% C and had ultimate strengths of 63,400 lbs./in.^{2} and 59,300 lbs./in.^{2}, respectively.

All welded specimens had butt welds, and tests were made with the joints as-welded or flush-planed-reinforcement and stress-relieved or not stress-relieved. A few tests were also made on a manganese-vanadium low-alloy structural steel.

For the carbon steel specimens in the as-welded condition, the values of the fatigue strength for a cycle in which the stress varied from tension to an equal compression were 21,600 lbs./in.^{2} for failure at 100,000 cycles, and 14,800 lbs./in.^{2} for failure at 2,000,000 cycles; and for a cycle in which the stress varied from zero to tension, the values of the fatigue strength were 32,600 lbs./in.^{2} for failure at 100,000 cycles, and 23,100 lbs./in.^{2} for failure at 2,000,000 cycles.

For specimens in the as-welded condition, except that the reinforcing had been machined off flush with the base plate on both sides, the values of the fatigue strength for a cycle in which the stress varied from tension to an equal compression were 29,400 lbs./in.^{2} for failure at 100,000 cycles, and 19,800 lbs./in.^{2} for failure at 2,000,000 cycles; and for a cycle in which the stress varied from zero to tension, the values of the fatigue strength were 47,000 lbs./in.^{2} for failure at 100,000 cycles and 30,100 lbs./in.^{2} for failure at 2,000,000 cycles.

Thus, removing the stress raiser due to the change in section at the edge of the reinforcing, increased the fatigue strength 43%. Moreover, the fatigue strength of the welded specimens with the reinforcement planed off was equal to the fatigue strength of plates without welds. Stress relieving the specimens by heating them to 1200° F. for one hour and then cooling them in the furnace had no effect upon their fatigue strength.

For all kinds of specimens, stress-relieved or not stress-relieved, reinforcing off or reinforcing on, the fatigue strength corresponding to failure at 2,000,000 cycles in which the stress varied from tension to tension one-half as great, exceeded the yield point of the material, and is therefore not important to the structural designer. The relatively small variations in hardness and the favorable grain structure indicate that there were no major metallurgical stress raisers present in the welds to affect the fatigue strength.

Favorable values for fatigue strengths of *weld-metal* laid down by the Unionmelt process are reported by L. B. Durant & J. F. Ennis of Webb Inst. of Naval Architecture ("Investigation of the Fatigue Strength of Weld Metal and Welded Butt Joints in the As-Welded and Stress-Relieved Conditions," *Welding J., N. Y.*, Vol. 19, Feb. 1940, pp. 615-655). The as-welded figure was 35,300 lbs./in.^{2} and stress-relieved, 30,700, showing stress relief to be harmful to fatigue properties. The endurance limit of the *welded joint* was found to be 26,400 lbs./in.^{2} for both the as-welded and stress-relieved conditions. The weakest part of the joint was in the base metal at the junction of the grain-refined zone and the unaffected parent metal. CEJ (3a)

Tin Bearing Sheet Steel

"Residual Tin in Steel." Paul J. McKimm. *Steel*, Vol. 106, May 6, 1940, pp. 64, 67-68; May 13, 1940, pp. 60, 64, 69. Investigation.

It has been maintained that extra deep-drawing sheets should not contain more than 0.015-0.025% Sn. To determine the effect of tin in sheet steel, tests were conducted with material processed by the continuous cold-strip method and box annealed. Results of tests of sheets made from steels containing 0.012, 0.014, 0.016, 0.022, 0.047, 0.052, 0.057 and 0.078% Sn in ladle indicated that higher tin content

had no deleterious effect on physical properties.

For example, the properties of material made from steel with 0.078% Sn and annealed at about 1300° F. (held above 1240° F. for 19 hrs.) were: Rockwell B hardness, 43/44; Olsen, 0.419 in.; elastic limit, 25,630 lbs./in.^{2}; ultimate strength, 46,370 lbs./in.^{2}; and elongation in 2 in., 53%, in 4 in., 41.5%, and in 8 in., 32.8%.

Other heats were made using iron containing tin and an increased quantity of bundled tin scrap in the open-hearth furnace charge. A heat that contained 0.12% Sn and 0.40% Cu was processed according to ordinary routine procedure. Physical properties conformed to normal standards. After skin passing, further tests were made 72, 168 and 336 hrs. later. There was an increase of 3 Rockwell B, which agreed with results generally obtained. This material was then applied to several severe drawing parts and the performance was very satisfactory.

The properties of hot-rolled strip made from a heat containing 0.21% Sn and of regular material of the same gage and treated identically, were, respectively: Elastic limit, 39,230-41,350 and 40,000 lbs./in.^{2}; ultimate strength, 52,800-54,620 and 52,000 lbs./in.^{2}; elongation, 38-42 and 40% in 4 in.; and Rockwell B hardness, 53 and 57.

There is considerable tin segregation in low-carbon rimmed steel, but tin up to 0.124% does not noticeably affect the physical properties and workability. Tin contamination can certainly be far more extensive than previously contended, but how high it may be without causing difficulty in the performance of extra deep-drawing sheets has not been determined. Intensive study of copper contamination in steel sheets indicated it had no effect on physical properties. Chromium and nickel each up to 0.10% apparently have no effect on physical properties of deep-drawing sheets, but appear to increase stiffness. MS (3a)

Rails

A Composite

The annual progress reports on the investigations of rails at the University of Illinois (*Proc. Am. Railway Eng. Assoc.*, Vol. 41, 1940, pp. 673-763) cover the topics that have long been under study: Transverse fissures, end batter, and (*Ibid.*, pp. 735-755) continuous welded rail. These are also available as *Univ. Ill. Eng. Expt. Sta.* Reprints Nos. 16 and 17.

Controlled-cooled rails, processed to avoid shatter cracks, have been in service long enough for an appraisal of the efficacy of slow cooling. Several rail failures occurred in such rail, but examination showed that the causative flaws were seams, wheel burns, or unusual aggregations of inclusions, not shatter cracks. A few of the rails made by the Brunorizing process before the process included a 2-hr. hold above 1000° F. before entering the furnace, failed by typical shatter cracks and consequent transverse fissures, but no such cases have been met in rails processed according to the present recommended practices for slow cooling or Brunorizing.

The effect of variations in cooling practice was extensively studied. It was concluded that, in the regular insulated containers used to slow the cooling rate, a period of 7 hrs. in cooling from 700° to 300° F. suffices to avoid shatter cracks, and that, after holding at the following temperatures for the following times, air cooling is not dangerous: 1100° F. for 3 hrs.; 900°-700° F. for 4 hrs; 500° F. for 5 hrs.

Cooling curves and tests are given supporting these conclusions. No rail should cool to 300° F. in less than 7 hrs., and container insulation and loading practice are being standardized to insure no faster cooling rate.

Rail ends, hardened by a variety of processes, some at the mill, some in the track, were watched in service. Unhardened ends, originally around 245 Brinell, work-hardened in 6 months' service to about 275. Those originally hardened to 350-425 Brinell remained at about their original level, while those hardened to 315-350 rose to 350-365.

The hardness distribution and the metallographic structure produced by various treatments are shown. Room temperature tensile and impact tests on specimens representing hardened material showed no depreciation in these properties and, in general, an improvement. Specimens from rail heads cold-rolled by wheel loading in the laboratory so as to represent material work hardened in service, both from unhardened areas and from areas representing end-hardening were tested in unnotched Charpy impact, at room temperature and at zero F. The low temperature toughness, as measured by this test, was consistently improved by either cold work or quench-hardening, or both, within the hardness range studied. More work on this, and on fatigue of the hardened rails, is in progress.

In the hope of finding a non-destructive test that will differentiate between a sound and a shatter-cracked rail at the mill, an "echo" method was briefly examined, without promising results. To aid in the tech-

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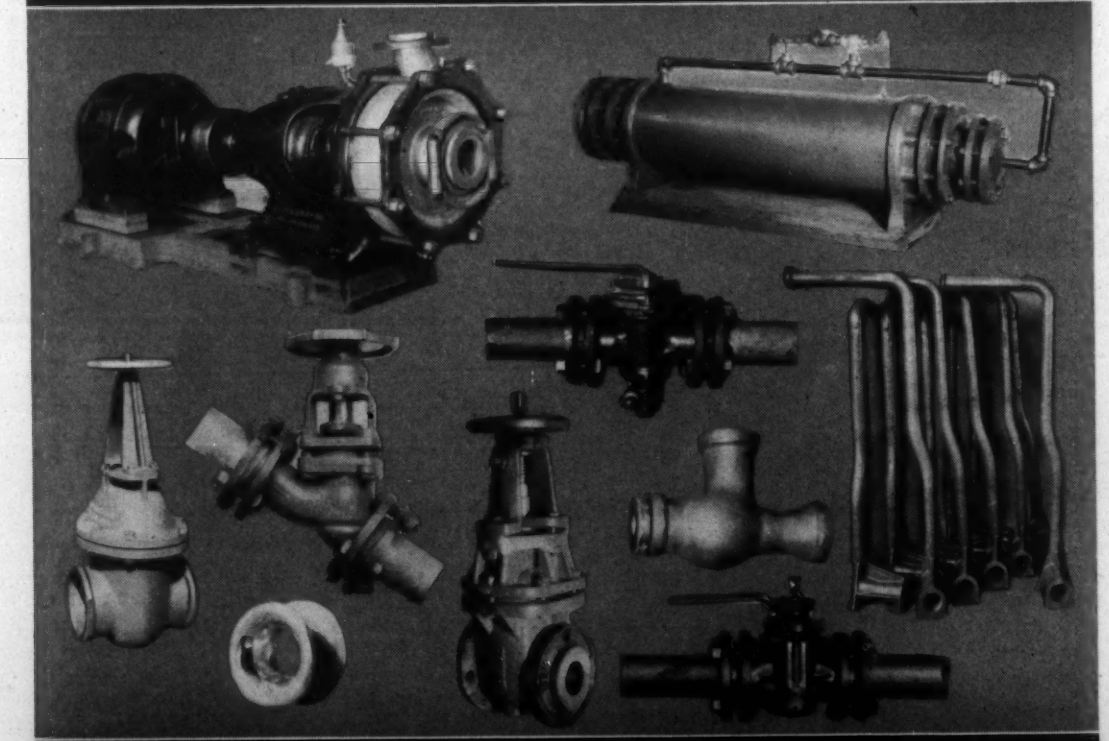

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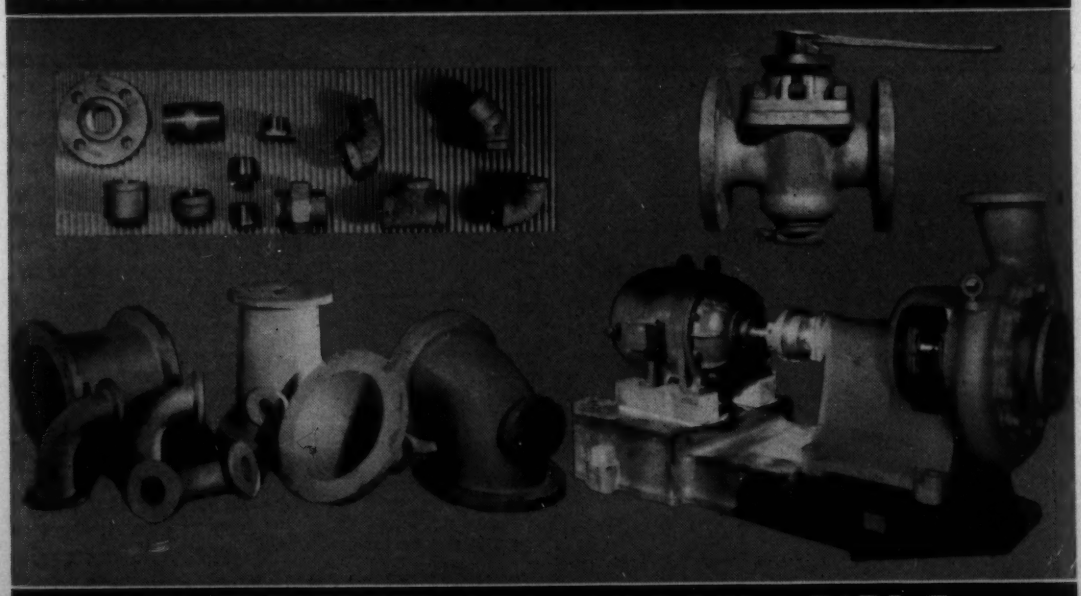

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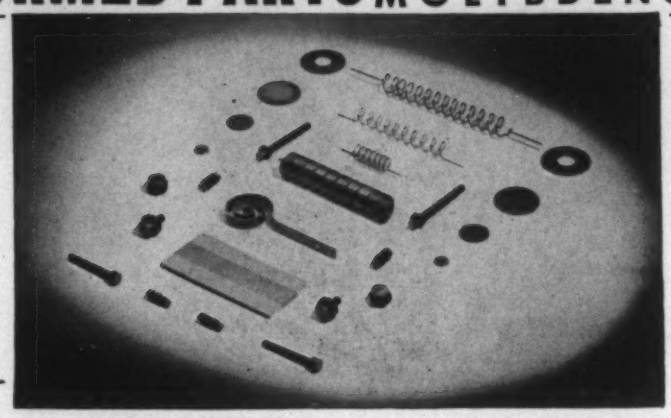

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nique of detector car operation, a study was made of the variations in the magnetic field due to a fissure. Some data are given on detector car operation, and a laboratory rolling-load test for joint batter is discussed.

The standard drop test for accepting or rejecting rails is a sort of go or no-go method which does not give much insight into the real properties of the rail. A bend test offers a more illuminating method. A preliminary correlation is made from old data and suggestions are offered as to an approach to a comprehensive evaluation.

The work on continuous welded rail included fatigue tests by repeated rolling wheel load applied over the welds made by the various processes, and bend tests of the same types of welds, compared with rail joints connected by joint bars. These can be summed up by stating that welding without applying pressure to the plastic joint is inferior, while electric or gas welding *with* pressure gives results better than the joint bars, and thermit welding with pressure, nearly as good.

Metallographic examination of certain thermit welds made by a supposedly improved technique showed oxide inclusions. Fig. 8 of this report, compared with Fig. 9 of the companion report, which shows aggregations of inclusions in a rail that developed a fissure in service, indicates that the thermit method should be still further improved to avoid possibility of such oxide inclusions. This is not brought out in the report, but is perfectly apparent to any reader of both reports.

Mechanical tests on specimens cut from the heads, welds, and bases at welds made by the various processes included static tension, tension impact and endurance. These lead the reader to the same conclusion as did the tests on full rails, *viz.*: gas or electric welding with pressure, excellent; thermit with pressure, doubtful; gas without pressure, rotten. The report says that whatever conclusions the reader draws, he must remember that service records furnish the final criterion.

Through the years of these investigations the quality and practicality of the work has been outstanding, as has been the refusal to draw premature conclusions. In short, it has been just what one would expect in any project steered by Professor H. F. Moore. HWG (3a)

3b. Non-Ferrous

Gallium for Tooth Fillings?

THE PROBLEM OF SUBSTITUTING GALLIUM FOR MERCURY IN TOOTH FILLINGS ("Zur Frage der Ersetzbarkeit des Quecksilbers in Zahnplomben durch Gallium") FRIEDRICH WEIBKE & ERICH HESSE. *Z. Elektrochem.*, Vol. 46, Mar. 1940, pp. 219-222. Original research.

A part of the silver-tin-gallium system was investigated by thermal, macroscopic and X-ray methods. The temperature at the end of solidification is of particular importance for dental applications. With increased silver or tin contents the temperature at which melting begins increases very rapidly.

This behavior is different from that of mercury alloys. Mixtures similar to those with amalgams were prepared using gallium; alloys containing from 10-50% Ga were investigated. The gallium-rich samples were plastic and could be formed easily, but the others tended to crumble.

After pressing the mixtures into a mold and leaving them there for 1-2 hrs., they were removed and stored for 1-2 days, after which the Brinell hardness was to be determined. However, the samples cracked before the full load (62.5 kg., 2.5 mm. ball) could be applied. This is attributed to the softening of the solid solution with increasing gallium content.

Alloys with less than 15% Ga have sufficient hardness, but their melting points are too high. It is concluded that silver-tin-gallium alloys cannot be used as filler materials in tooth cavities in place of silver-tin amalgams. RPS (3b)

Copper-Beryllium-Manganese

"STRUCTURE AND PROPERTIES OF COPPER-BERYLLIUM-MANGANESE ALLOYS." N. A. FILIN & P. K. GINZBURG. *Metallurg*, Vol. 14, Dec. 1939, pp. 9-19. In Russian. Research.

The alloys investigated contained up to 5% Be and up to 12% Mn. Within this region there are three fields of primary separations: α, β, and x-phases. The region of the ternary α solid solution decreases with increasing manganese content and with decreasing temperature.

At temperatures of 575° and 660° F. all these alloys are susceptible to aging. The largest aging effect was observed for the alloys having 1.2-2% Be and 2-4% Mn. By increasing the manganese content the aging effect decreases. The greatest hardness is reached at 660° F., but the best aging temperature is 575° F.

By increasing the beryllium content the tensile strength rises. This is also true when the manganese is increased up to 4%, but with further addition of manganese the tensile strength drops. Alloys having a tensile strength of 100,000-112,000 lbs./in.^{2} and an elongation of 13.5% were prepared. BZK (3b)

Designing for Die Castings

A Composite

"Designing for die castings" means a lot more than just deciding to employ die castings rather than sand castings or stampings or permanent mold castings or screw-machine products or plastics in a product. It means, in addition, designing the part or product so as to make use of every possible advantage that the die casting method can provide, and also avoiding certain die casting design practices that are disadvantageous from either cost, production-rate or quality standpoints.

The factors involved in selecting or not selecting die castings for individual products have been reviewed in earlier issues of METALS AND ALLOYS ("Metals and Plastics," Feb. 1940, p. MA 94; "When to Use Die Castings," Apr. 1940, p. MA 218). The specific design points to be borne in mind once die castings have been selected are discussed herewith.

Some General Hints

In all cases, the closest possible understanding and consultation between the die caster and the die casting user should exist. For example, it is pointed out in one article ("Making the Most of Die Castings," *Electrical Manufacturing,* Vol. 25, Jan. 1940, pp. 53-56, 92) that although die castings often save a great deal of machine work, there are many cases where some machining is necessary to hold to required limits. Often a little light machining in the right places avoids the undue complexity of die that would result if the latter were expected to do the whole job.

Designers should try to visualize the piece within a rigid die in which it is to be cast and from which it must, of course, be removed readily when cast. The die should part in one plane, at right angles to the tie bars on which the movable portion slides. The widest part of the piece should be at the die parting to clear the die, otherwise separate slides must be used. Complex pieces can be studied to best advantages from full size wood or clay models.

Assembly operations and considerable machine work can often be avoided by die casting in one piece, using integral-cast lugs, bosses or flanges for supporting or attaching other parts of the product. Often separate die cast parts can be produced simultaneously in one die with multiple cavities.

Holes, Sections and Corners

Parts should be so designed that as many as feasible of the recesses and holes required can be formed by cores. Holes running parallel to die motion may be made by cores either integral with or inserted in the main portions of the die. Other holes require movable cores or slides with positive operating mechanisms that tend to increase costs. Sometimes small holes can be drilled more cheaply than they can be cored.

It is better to provide for coring out thick sections than to cast them solid, unless adjacent sections are of about equal thickness. Within certain limits, the thinner the section, the sounder the casting is likely to be. Abrupt changes in section thickness should be avoided.

Considerable weight can be saved by making sections as thin as strength considerations permit. Certain types of zinc alloy die castings can be cast hollow and subsequently formed in a stamping die to yield a closed section with a concealed joint, giving adequate strength and required solidity, with saving in weight and metal.

Generous fillets are recommended, of course, especially at inside edges. Sharp external edges, too, are likely to make polishing and buffing more difficult and result in buffing-through plated edge-surfaces. Buffing and polishing of recesses is difficult unless they are shallow and have large radii, and the same is true of inside edges unless liberal fillets are employed.

Stiffeners

Ribs are often used to great advantage to stiffen large thin sections and at points where such sections require bosses. Integrally-cast bosses or lugs must not introduce undercuts. They can sometimes be made hollow and still have the required strength, with improved uniformity of section thickness for the casting as a whole. Important economies can often be realized by casting integrally rivets for fastening to other parts.

Inserts possessing greater strength or hardness or other properties different from the castings themselves can often be cast in place, although this increases the cost. Inserts should be knurled, so as to be locked positively in the casting if service involves pulling or turning. Inserts used in zinc alloy die castings, if plated, should be plated with zinc.

Although die castings are cast to within extremely close limits, tolerances should not be excessively narrow, if costs are to be kept down. In general, practice dimensions on which limits are not specified may vary from ± 0.007 in. up to ± 0.016 in., except in the case of very large pieces, in which tolerances are greater.

Large flat surfaces should be avoided; slight crowning is much to be preferred. Large flat surfaces should be stiffened by ribs if sections are thin. Ejector pins, for forcing die castings out of the die and off of cores, leave unsightly marks where they strike the casting, and their location should be carefully chosen; they should be designed to bear on flash or runners, which are later cut away, wherever possible. Intersecting cores should be avoided; occasionally, it is better and perhaps cheaper to drill or punch one or both of the holes.

Undercuts should, of course, be avoided. Certain types are feasible, although they involve extra die slides, collapsible cores, etc. When essential, they may be *machined* out later rather than cast with an undercut.

Special Advantages

Several interesting applications of principles like the foregoing to the design of machinery parts are described and illustrated in another article ("Die Casting Fundamentals Point Way to Extra Savings," *Machine Design,* Vol. 12, Mar. 1940, pp. 51-53). Thus, when a slot is cored in a die casting, the clearance produced by coring around the bosses helps to avoid difficulties in machining and assembling, such as guide-block seating.

Likewise, recesses cored around the ends of tapped holes prevent any burr thrown out in tapping from interfering with firm seating of the flat face of the casting against a mating part. Among the other cases described are a lever that was die cast with a split hub and with an insert cast in the boss at the outer end.

Design considerations involved in sticking closely to one-piece construction are featured in a third article ("Complicated One-Piece Parts Made by Die Casting," *Steel,* Vol. 106, Mar. 11, 1940, pp. 42-43, 79). Gears with tooth profiles so accurate as to require no machining; stepped spur gears cast integrally with nine to a unit; and spur and bevel gears combined with a common hub having eight integral ribs with a brass bushing cast in place are among the many designs—all in zinc alloy die castings—illustrated.

Still other design features are discussed in a "choose which" article by HERBERT CHASE ("Die Cast or Sand Cast—II", *Product Eng.,* Vol. 11, Apr. 1940, pp. 165-168). The large majority of the design kinks just described have no counterpart in sand casting, as is evident from a comparison of die-cast and sand-cast compound rest swivels for lathes, washing machine housings and various business machine parts.

FPP (3b)

Cemented Carbide Applications

"THE BROAD FIELD OF USE FOR CEMENTED CARBIDES." J. R. LONGWELL (Carboloy Co., Inc.) *Wire & Wire Products,* Vol. 15, May 1940, pp. 249-251, 271. Review.

Cemented carbides are among the major products manufactured by powder metallurgy. Tungsten carbide is the most widely known type and the familiar tungsten carbide cemented with a cobalt binder enjoys the largest poundage consumption by industry of all carbides. It is, furthermore, the basis for almost all industrial carbides.

The industrially useful materials commonly referred to as tantalum carbide and titanium carbide usually have as their base materials tungsten carbide to which small proportions of tantalum carbide or titanium carbide (or both) are added. These bi-carbides and tri-carbides are largely used as cutting tools for machining steel, a field in which tungsten carbide alone is not fully satisfactory.

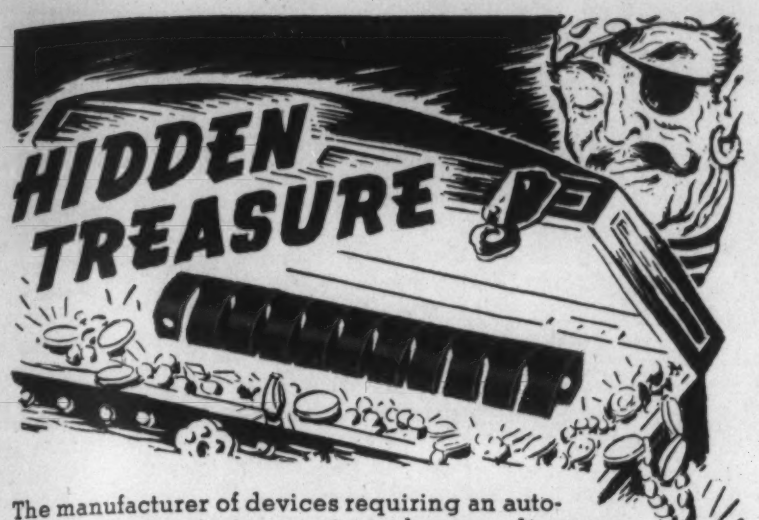
The tantalum carbide grades have found some use, in addition, for dies used in wet-drawing pin wire, wearing wire, etc. The suitability of the combination carbide for drawing copper has yet to be established. Despite the inclusion of about a dozen different carbides in the line of some manufacturers, for all cutting tool applications two grades would suffice—one grade for cast iron, brass, bronze, plastics, etc., and the other for steel. Of course, simple tungsten carbides for steel wire drawing have been completely standardized, each manufacturer usually offering but one universal grade for this purpose.

Abrasion-resistant applications are growing. The wire products manufacturer uses carbide inserts for pitch tools, coiling points, etc. In sheet metal work, tungsten carbide tools serve for blanking dies, drawing dies, redrawing dies and sizing dies—some with holes as large as 6½ in. diameter. Carbide dies are used for sizing bolts, and recently for cold forging, swaging and cold heading. Carbide rolls have been employed for rolling bronze spring stock.

Gages, guides and bushings are other wear-resistant applications. New is the automotive industry's use of tungsten carbide on the "shoes" on which camshaft bearings turn during grinding. Carbide grinder and lathe centers are increasingly common. Carbide-tipped collets are employed on automatic screw machine parts. Carbides have eliminated the thread-fraying previously caused by steel guides and bushings in the textile field.

Fish rod guides, carpet-needle eye inserts, wire rope strander rings, anvils on wire stapling machines, needle-valve and bolt-valve seats, bread-slicing knife guides, and jig bushings are among the many wear-resisting applications of cemented carbides adopted by engineers in several industries.

FPP (3b)



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Life Testing Electrical Heating Alloys

A Composite

European and American methods for testing the high-temperature life of electric resistor alloys differ considerably. American practice has been standardized by the A.S.T.M. with a test in which a straight wire of standard length and gage is mounted vertically with a 10-g. weight attached to the lower end of the specimen, and tested at constant voltage after starting at a standardized temperature. In Europe, attempts at standardization have been complicated by the great variety of resistor types, with their various high-temperature properties and, of course, by international boundaries.

Europeans tend to favor helically-coiled samples rather than straight-wire. They also avoid the creep factor (introduced by the suspended weight in the American test) through careful support of the metallic element. The "supported" European tests show the iron-base resistors to much better advantage than does the weight-attached American test. The latter was designed for testing the nickel-base alloys widely used here, and may not be a truly fair test of the quality of low-creep-strength, iron-base alloys intended for "supported" service in domestic appliances.

Suggestions for a German standard life test are given in a group of articles by W. FISCHER ("Die Lebensdauerprüfung von Heizdrähten," *Elektrowärme*, Vol. 10, May 1940, pp. 59-64), W. HESSENBRUCH ("Beitrag zur Frage der temperaturmessung bei der Heizleiterprüfung durch Lebensdauerbestimmung," *Ibid.*, pp. 65-68), and R. ADELHEIDT & W. FISCHER ("Zur Frage der Temperaturmessung bei der Lebensdauerprüfung von Heizdrähten," *Ibid.*, pp. 68-73).

Much attention is paid to the importance of the form of the sample and method of measuring temperature. The standard method suggested employs helical coils of 0.4-mm. diam. wire, enclosed in small ceramic tubes and temperatures of 1920° F. for 80 Ni, 20 Cr alloys, 1920° F. for 35 Ni, 20 Cr, 45 Fe alloys, and 2200° F. for 30 Cr, 5 Al, 65 Fe alloys. Temperature maintenance and control are complicated by variations in the ratio of length to diameter of helix, and tables of suitable correction factors are given.

Study of an article by F. E. BASH of Driver-Harris Co. ("Life Expectancy of Electrical Heating Elements," *Metal Progress*, Vol. 37, Jan. 1940, pp. 39-42) reveals how widely apart are American and European philosophies on testing heater wire. Mr. Bash describes the adaptation of the A.S.T.M. test to the estimation of life-expectancy at various temperatures from test data on the life at one standard temperature.

Such extrapolation is possible because, as is shown, each of the 80 Ni, 20 Cr and 60 Ni, 16 Cr, 24 Fe alloys has a constant and characteristic life-temperature relation; the constants for the Driver-Harris alloys are given. Tests on the 80/20 alloy are ordinarily run at 2150° F., as compared with the Germans' 1920° F. (This may or may not be a reflection of a quality differential between German and American materials.)

Also, calculations for "expected life" at one temperature from standard test data at another can be applied to "total life" or to "useful life" (life to 10% resistance increase) indiscriminately only for temperature ranges and materials where the ratio of "useful life" to "total life" is uniform, and fairly large. For alloys whose "useful life" at the test temperature is only a small fraction of the "total life," only the "useful life" should be used as a basis.

[Herein lie the seeds of international discontent. The iron-base alloys popular in Europe have a "useful life" in the A.S.T.M. test that is much shorter than the "useful life" of American nickel-chromium alloys at temperatures around 2000° F. But the "total life" of some of the iron-base alloys is likely to be longer than the best nickel-chromium alloys in the A.S.T.M. test and in various European tests.

The cause of this seeming discrepancy is the little 10-g. weight that is hung on the sample in the American test. Intended to keep the specimen straight, it actually exerts a stress of about 40 lbs./in.^{2}, which causes only an inappreciable length-extension (and, therefore, resistance-increase) in the nickel-chromium alloys but does have a noticeable effect on the iron-base materials. —F.P.P.] X (4)

X-Rays and Alloy Structure

"RESEARCHES INTO THE STRUCTURE OF ALLOYS." A. J. BRADLEY, W. L. BRAGG & C. SYKES. *J. Iron Steel Inst.*, Adv Copy, May 1940, 80 pp. See also *Iron & Steel*, Vol. 13, May 1940, pp. 305-307, 308-310. Summary of 3-yrs. work of the British "Structure of Alloys Research Panel."

New understanding of metal behavior is available in X-ray investigation of atomic patterns. Older methods permitted exploration of equilibrium diagrams for 2-components. This type of work is in its infancy, but there are already indications of general laws and of a theoretical explanation of the crystalline patterns formed in alloys. Highly trained men are now available with a knowledge permitting the invaluable application of X-rays to practical problems.

The microscope can reveal structures only of an order larger than the wave length of light, and at 2500X details must be on a scale 10^{-4} cm. to be visible. Distances between atoms in many common metals are 2.4 and 2.8 x 10^{-8} cm; X-ray analysis conveniently covers this range. Heat treatment and precipitation effects can be measured by X-rays. Grain size, state of strain and preferred orientation resulting from distortion by cold-work can likewise be determined, shedding light on the mechanism of cold-rolling, cold-drawing and similar processes.

X-Rays and Mechanical Behavior

X-ray diffraction pictures enable an investigator empirically to correlate small-scale structures with bulk physical, mechanical, and service properties as surely as though he were looking at the actual sub-microscopic structure. Concerning mechanical strength, if one imagines a mass of positively charged shot (atoms) permeated by a negatively charged fluid (electrons) so that the attraction between shot and fluid holds the whole mass together, we have an illustrative working model of a metal. The ductility of a metal, its plastic flow along glide planes, its recrystallization on annealing and the diffusion of one metal through another in the solid condition are consequences of the peculiar nature of the metal structure.

Shear resistance exists only when crystal perfection is destroyed by cold work, or when various kinds of atoms are present. The easy glide along crystalline planes is disturbed by resulting irregularities, indicating that strength is of a secondary character not dependent on inner crystalline structure but influenced more by crystal orientation. Alloy additions may serve a direct effect on increased physical properties by promoting ripples or irregularities in composition, or may be indirectly responsible by varying transformation rates to make the alloy heat-treatable on a practical scale.

Superlattices

With respect to order-disorder transformations, the atoms of some two-metal alloys solidify from the melt on a regular lattice with random distribution of either kind of atom among the points of the lattice. At a temperature far below solidification a "second crystallization" occurs, atoms rearranging by migration until the two kinds are in regular arrangement. This type of transformation differs from an allotropic change since the same lattice points are occupied by the atoms before and after the change.

As an analogy, one may picture an array of regularly arranged boxes and an equal number of red and white balls. The high temperature state is represented by filling the boxes with balls regardless of

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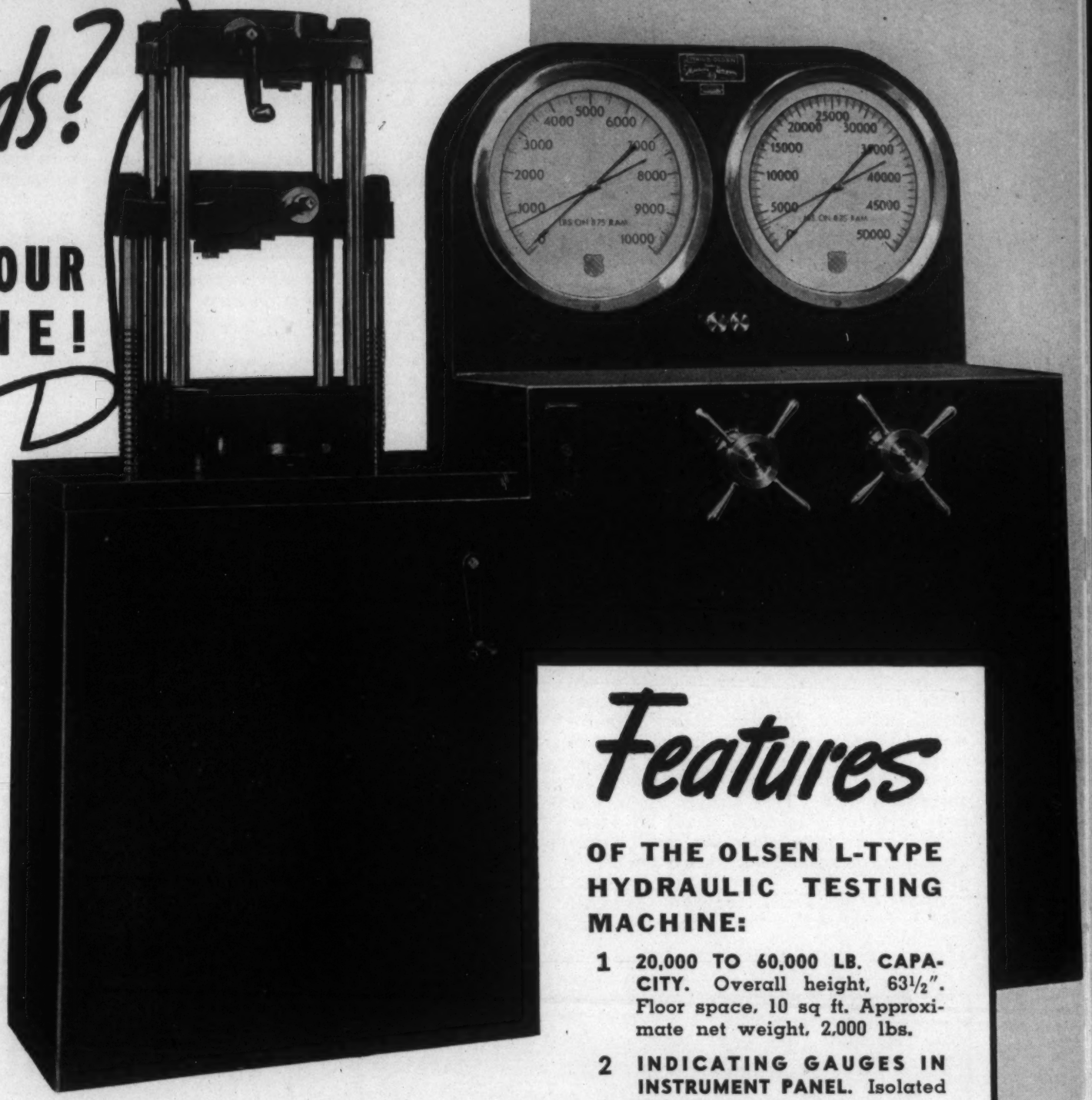

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color, the low temperature state by rearranging into a checker pattern of red and white, similar to the copper-zinc, beta brass transformation.

All instances of order-disorder transformations so far discovered occur in alloys whose compositions conform closely to the form AB or AB_3. This transformation is a "cooperational phenomenon," the ordered structure existing at low temperature since it has a lower internal energy than the disordered structure. The "cooperational" feature lies in the tendency of A atoms to remain in an ordered position simply because the B atoms are in that state.

Similar to this superlattice formation is the phenomenon of ferromagnetism, a metal-like iron or cobalt losing this property as the temperature is raised above the "Curie" point. At thermal ranges below this point the "elementary magnets" assume a mutually aligned, more or less parallel, orientation, each pointing in the direction chosen by the majority of its neighbors. As the temperature is raised its disruptive influence throws the magnets more and more out of alignment until the intrinsic magnetism vanishes at the Curie point.

Thermal Factors

Since it requires energy to shift atoms from an ordered to a disordered arrangement, and since this shift occurs with increasing temperatures, heat has to be supplied in excess of that required for thermal vibrations, thus making the specific heat abnormally high. This value is measurable and rises to a marked maximum many times normal just below the critical temperature, falling as soon as the critical is passed.

Alloys of the Fe_3Al type showed atomic rearrangement during cooling from 700° C., the extent being dependent on the rate of cooling and atomic composition. This shed light upon anomalies in electrical resistivity and coefficient of expansion noted in iron-rich iron-aluminum alloys. A similar transformation that occurs in Ni_3Fe may have a bearing on the remarkable magnetic properties of alloys of the permalloy type.

Age hardening phenomena, too, are being studied by specific heat measurements, it being found that precipitation from a supersaturated solid solution is accompanied by an evolution of heat. Merica's theory of a submicroscopic precipitate and Gayler's version of a segregation of solute atoms on the parent lattice are experimentally confirmed, but different alloy systems exhibit different structures to be associated with maximum hardness. HFT (4)

Static Crack Strength

"Static Crack Strength of Metals—Its Determination and Significance." M. Gensamer (Carnegie Inst. Tech.) *Metal Progress*, Vol. 38, July 1940, pp. 59-64. Research.

The "static crack strength" is the tensile stress required to propagate a crack in the presence of a very sharp and deep notch running transversely to the stress direction. Also known as the "technical cohesive strength," the concept is of interest to engineers, for it is the same limiting value which yield strength, ultimate strength and stress at fracture all approach as the notch is increased in depth and sharpness.

The employment of static crack strength tests and their correlation with service failures and other notch-sensitivity tests have been restricted by the difficulty of machining the necessary perfectly sharp notches, especially in hard metals. Two methods are described for producing deep sharp notches or cracks in hard steel that require little time and skill for their success. Both start with machined 60° notches, which demand no greater sharpness or precision than any competent mechanic could provide.

The first method consists of sharpening this machined notch by filing it with an ordinary 60° triangular file that has been smoothed (edge "sharpened") by rubbing two adjacent faces against metallographic polishing paper or a fine tool sharpening stone. Perfectly brittle fractures, without measurable plastic deformation, were obtained with notches so produced. The only disadvantage is the need to develop considerable skill in filing.

The other method comprises extending this machined notch (after polishing it) into a full-fledged fatigue crack by running it in a rotating cantilever-beam fatigue machine equipped with collet chucks, with a capacity of 40 in.-lbs. bending moment, and operating at 10,000 r.p.m. This gives a circumferential crack of the required depth (controlled by a micro-switch under the end of the beam) after 10,000-20,000 revolutions. There is no evidence, however, that the number of revolutions required has any effect on the technical cohesive strength measured.

This technique produces surprisingly regular fatigue cracks, completely around the specimen, of reproducible depth and easily measurable area. Special tests also showed that the fatiguing process changes the value of the technical cohesive strength finally obtained relatively little.

In the static crack strength test itself, the specimens, cracked by either of the foregoing methods, are screwed into a suitable adaptor and broken in tension. Properly

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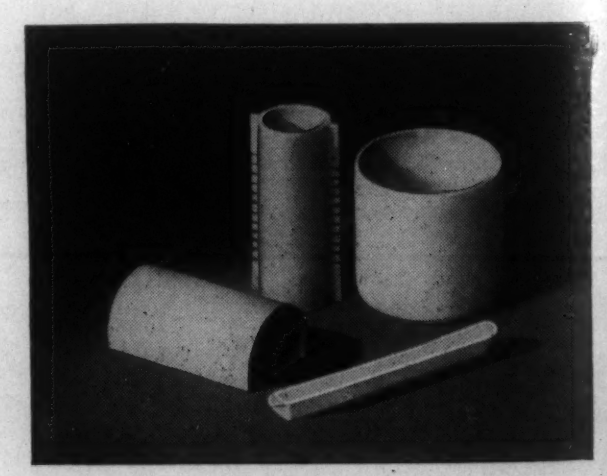

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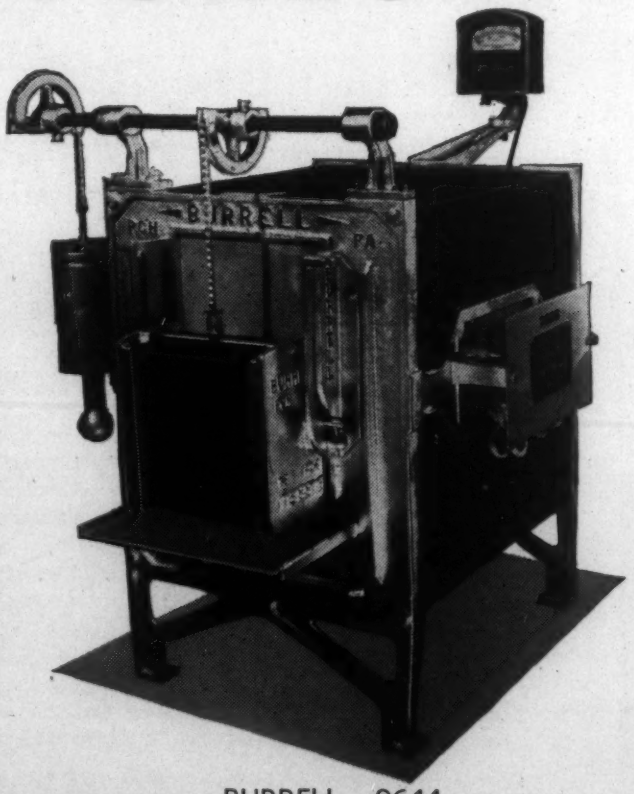

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cracked specimens break as the load is increasing—there is no evidence of yielding until fracture occurs. If the load reaches a maximum and begins to diminish before fracture, the test is discarded, for plastic deformation has occurred.

Technical cohesive strength test results on a given steel were substantially the same for samples notched by filing, by fatigue cracking, or by the earlier laborious method originally employed by W. Kuntze in his fundamental investigations.

Some interesting test results have already been obtained. The state of stress prevailing during prior plastic deformation (say cold rolling, stretching, etc.) affects the static crack strength. Although a difference in notch toughness (Charpy) was obtained in a steel (S.A.E. 4140) by coarsening the austenitic grain from 7 to 3, no significant difference in technical cohesive strength resulted. Technical cohesive strength can also vary over a wide range in quenched-and-tempered steel of the same hardness, depending on time and temperature of tempering. FPP (4)

Testing Damping Capacity

"The Damping Capacity of Steel and Its Measurement." G. P. Contractor & F. C. Thompson. *Iron Steel Inst.*, Adv. Copy, May 1940, 45 pp.; *Iron & Steel*, Vol. 13, No. 9, May 1940, pp. 311-317. Research.

All extraneous resistances excepted, a freely vibrating body will continuously decrease in amplitude, ultimately reaching a state of rest, because of an inherent property of the material known as "damping capacity." First introduced by Föppl in 1923, this concept and property can be defined as "the amount of work dissipated as heat by a unit volume of a material during a complete reversed cycle of unit stress." It can be expressed as "internal friction," "crackless plasticity," "mechanical hysteresis loss," or, as in the present case, as "specific damping capacity" (S.D.C.) denoted by the ratio (loss of energy per cycle):(max. energy per cycle) and expressed in %.

The Föppl-Pertz apparatus for the measurement of damping capacity was found to yield unduly high values, mainly as the result of frictional losses between the stylus and the recording medium. To eliminate these, the instrument was modified so as to employ an optical recording device. Particular attention was paid to considerations of the effect of initial stress, bending, size of specimen and shape of specimen.

The method of measuring was by determination of the logarithmic decrement. For a given amplitude y, the logarithmic decrement is $D = {}^{dy}/_{y}$, the S.D.C. being the ratio of the loss of energy per cycle to the maximum energy of that cycle. Once D is known, the amount of energy dissipated per cycle can be calculated, and $P = 2D$.

As the maximum torsional fiber stress increased, the damping capacity decreased. As the temperature increased, the damping capacity increased. For a given stress, low carbon steels have higher damping capacities than harder ones, and ingot iron is extremely good. The damping capacity for sorbitic and troostitic structures is low and fairly independent of stress, while pearlite and martensite yield higher values and are more sensitive to conditions of stress. Indications are that at zero stress damping capacity has a definite, positive value with mechanical hysteresis loops for all stresses, however low. JLG + HFT (4)

[These authors found no variation in damping values between 792 and 453 cycles/sec. This is of interest in connection with the raising of yield point observed by Wood and Thorne (digested in our next issue) under cycles applied 2200 times/min. —H.F.M.]

Inspection with Ultrasonic Waves

The Non-Destructive Testing of Cast Parts by Means of Ultrasonic Waves ("Die zerstörungsfreie Werkstoffprüfung von Gussteilen mit Hilfe des Ultraschalls") F. Schroeder. *Giesserei*, Vol. 27, May 17, 1940, pp. 186-188. Descriptive.

Ultrasonic waves range in frequency from about 20,000 cycles/sec. to about 250×10^6 cycles/sec. The most effective way to produce ultrasonic waves is by the reciprocal piezo-electric effort, *i.e.* the exposure of a thin quartz plate, cut in a certain way from a larger crystal, to an electric alternating field so that the plate oscillates (contracts and expands) periodically.

When ultrasonic waves are used for testing defective stock or castings containing pipes, cracks, intercrystalline corrosion, etc., the sonic generator is placed close to the casting and the waves are either absorbed or reflected at the defective places. The flow of ultrasonic waves through the object can be measured either by an ultrasonic receiver or by an optical instrument; for instance liquids through which ultrasonic waves are passing act as a diffraction lattice so that a light ray also passing through it will show diffraction figures on a screen. The perfection of this method to castings and other solid metal-forms should give an easy means of detecting defects. Ha (4)

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The essence of the book is found in the latter half where are presented the results of the impact of curious low-temperature phenomena on modern theories of matter, the nature of superconductivity, the behavior of specific heats and magnetic properties of matter and the freakish antics of liquid helium below 2° K. Particular attention has been given to the definition and measurement of temperature, and to the intriguing problems of the approach to the absolute zero.

The experimental work discussed in this timely book was performed at the McLennan Laboratory in Toronto, one of the best equipped physical laboratories in the world! The authors are pioneers in low-temperature research, and their work will be of the greatest interest to chemists, physicists, engineers and metallurgists.

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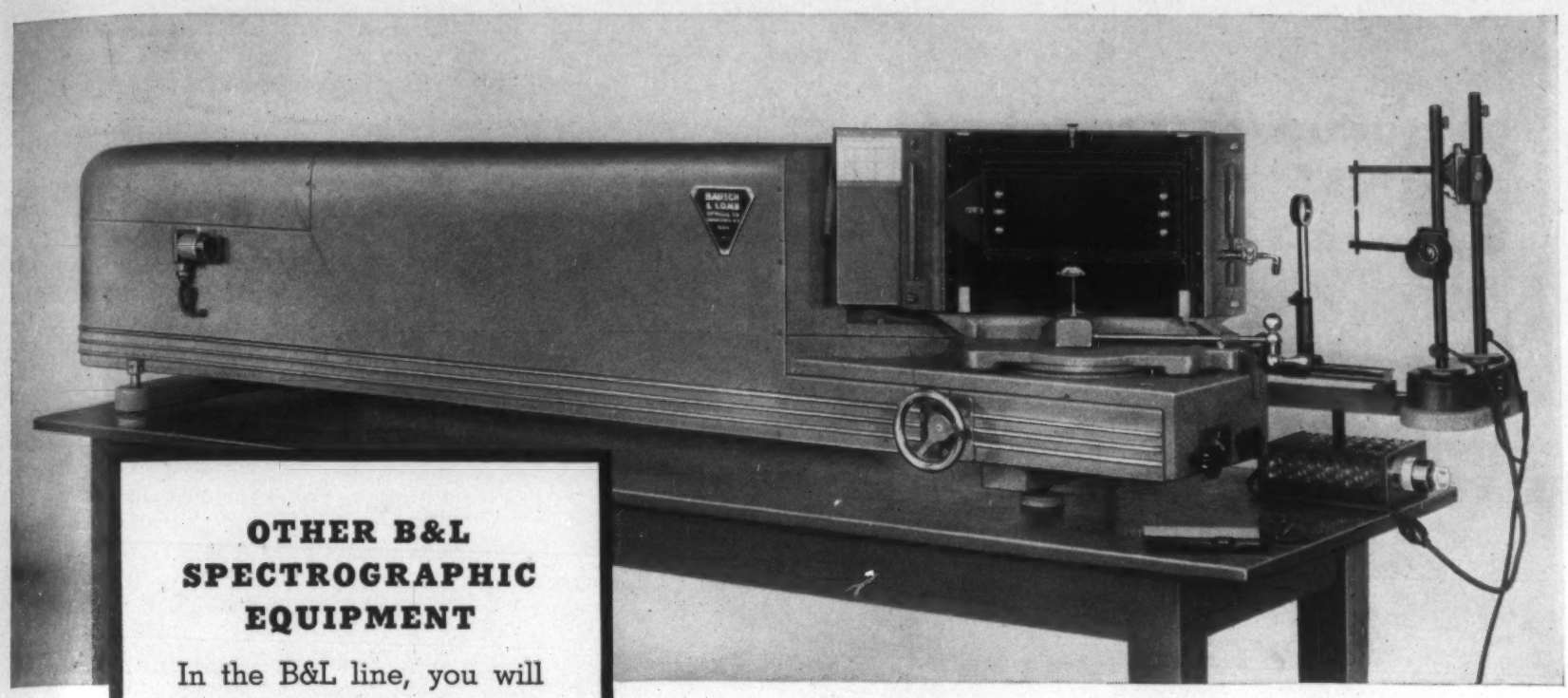

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books

Metals and Monopoly

TEMPORARY NATIONAL ECONOMIC COMMITTEE—VERBATIM RECORD OF THE PROCEEDINGS. VOLS. 2, 9 AND 11. *Published by The Bureau of National Affairs, Inc., Washington, D. C., 1940. Cloth, 9x11½ in., 580 pages, plus 148 pages of reference data; 632 pages; and 672 pages, respectively. Price $5.00 each, or $14.75 for the three.*

These three volumes contain considerable matter of interest to men in the metallurgical industries. In Vol 2, 47 pages (305-351) are devoted to the attack before the T.N.E.C. by the Federal Trade Commission on the basing-point and price-leadership practices of the steel industry. In the closing paragraph of this appears the statement, "The steel industry is a focal center of a monopolistic infection which, if not eradicated, may well cause the death of free capitalistic industry in the United States." Some reference to trade association practices is also in this volume.

Vol. 9 contains testimony (pages 53-418) of the heads of the major steel companies and of officials of iron mining companies and can companies in answer to interrogation on extras, pricing practices, export cartels, etc. Some of the testimony of Studebaker officials relates to steel for automotive use. Vol. 11 (pages 33-53, 60-225) discusses the copper industry, especially as to international limitation of production in times of low demand, with testimony from the copper executives. Pages 230-516 revert to steel, dealing with the topics of Vol. 9, plus that of identical bids.

Some of the high spots are the squabbles among four economists over the factual data prepared at great expense by the United States Steel Corp. and presented for the information of T.N.E.C. Much of the disagreement centered on what effect a price cut would have on consumption of steel, and was couched in peculiar technical phraseology. A representative of the Department of Justice summed up his opinion of the science of econometrics with the statement that a page of business facts is worth a volume of econometrics. Senator King presided at most of the steel and copper sessions and from time to time made comments inviting the viewing of the question at issue from the point of view of horse sense, but the comments seldom diverted the econometrists from talking to each other in their own language.

The steel and copper executives all showed a very broad-gage attitude, accepting at face value the T.N.E.C.'s statement that the hearings were for fact-finding, and not an inquisition. Except for the allegations of the Federal Trade Commission, the hearings were kept pretty much on that plane, though some of the New Deal economists were obviously trying to lay a foundation for acceptance of their own pet theories. The exhibits and prepared statements present much economic data on steel and copper, making the record useful source material.

To the lay reader, the side comments on N.R.A., regimentation, the account of the efforts of the copper companies to maintain employment at the mines when there was a glut of copper, and the picture of the executives of the steel business striving to produce some dividends for stockholders under highly difficult conditions, are the high spots. Only a very biased person could read this verbatim account without increased admiration for the men who run "big business."

The exhibits presented by the U. S. Steel Corp. are partly included in this record, but are fully shown in three volumes published last February by the corporation as "T.N.E.C. papers"—Vol. 1, 411 pages, Economic and Related Studies; Vol. 2, Chart Studies, 191 pages; Vol. 3, The Basing Point Method, 101 pages, all 8¼x11". The studies include evaluation of the conditions underlying variations in demand for steel in automobiles, railroads, tin cans and other containers, the relation of steel demand to general business conditions, the relation of steel prices, production and costs, and a section on improved quality as a price reduction. The volume on the basing point method assembles the historical facts and discusses the whole situation, in rebuttal to the attacks of the Federal Trade Commission.—H. W. GILLETT.

Die Castings

DIE CASTINGS. *By Arthur Street. Published in England and distributed by the Chemical Publishing Co., New York, 1939. Cloth, 5 x 7½ in., 160 pages. Price $1.75.*

This book, by an English author who has written many articles on this subject, is directed to the user of die castings. The use of these castings is so widespread—in automobiles, radios, washing machines and so on—that they are close to the daily life of many. The author discusses, in a simple manner, the design, purchase and application of this product in 26 chapters, including 5 tables and 47 illustrations. A bibliography is appended.—E. F. CONE.

Arc Welding

PROCEDURE HANDBOOK OF ARC WELDING DESIGN AND PRACTICE—SIXTH EDITION. *Published by Lincoln Electric Co., Cleveland, 1940. Cloth, 6 x 9 in., 1117 pages. Price $1.50 in U.S.A., $2.00 elsewhere.*

This handbook has been reissued so as to include all new data considered essential for the most efficient use of arc welding. It contains the results of 2 yrs. of fact finding by a staff of 200 arc welding application engineers throughout the world. It is encyclopedic in scope and contains 1557 illustrations.

Like all complete handbooks, it is of definite value to all those interested or active in arc welding.—E. F. CONE.

Statistics

ANNUAL STATISTICAL REPORT FOR 1939. *Published by the American Iron and Steel Institute, New York, 1940. Simulated leather, 6 x 9¼ in., 104 pages. Price $5.00.*

This compilation of production, capacity and other data of the American and Canadian iron and steel industries is of value to many. This particular edition is much the same as previous annual ones with a few exceptions: All data are given in net tons of 2,000 lbs. instead of gross tons—for the first time. Second—a table has been added to show production of the several descriptions of products rolled on continuous hot sheet-strip mills for the years beginning with 1935. The volume contains all the available data of the industries.—E. F. CONE.

Other New Books

IRON ALLOY SYSTEMS (DIE SYSTEME FE-MG BIS FE-PR). GMELINS HANDBUCH DER ANORGANISCHEN CHEMIE, 8TH EDITION. SYSTEM NO. 59 (IRON), PART A, SECTION 9. *Published by Verlag Chemie, Berlin, 1939. Cardboard, 7 x 10¼ in., 129 pages. Price 43.50 R.M.* Connected references to literature on binary and multi-component systems of iron with magnesium, alkaline-earths, zinc, mercury, aluminum, cerium, titanium, zirconium, tin, lead, vanadium, columbium, tantalum. Galvanized and tin coatings receive much attention. As this section finishes Vol. II of Part A, it is accompanied by a 2-volume index to sections 1-9 of Part A on iron.

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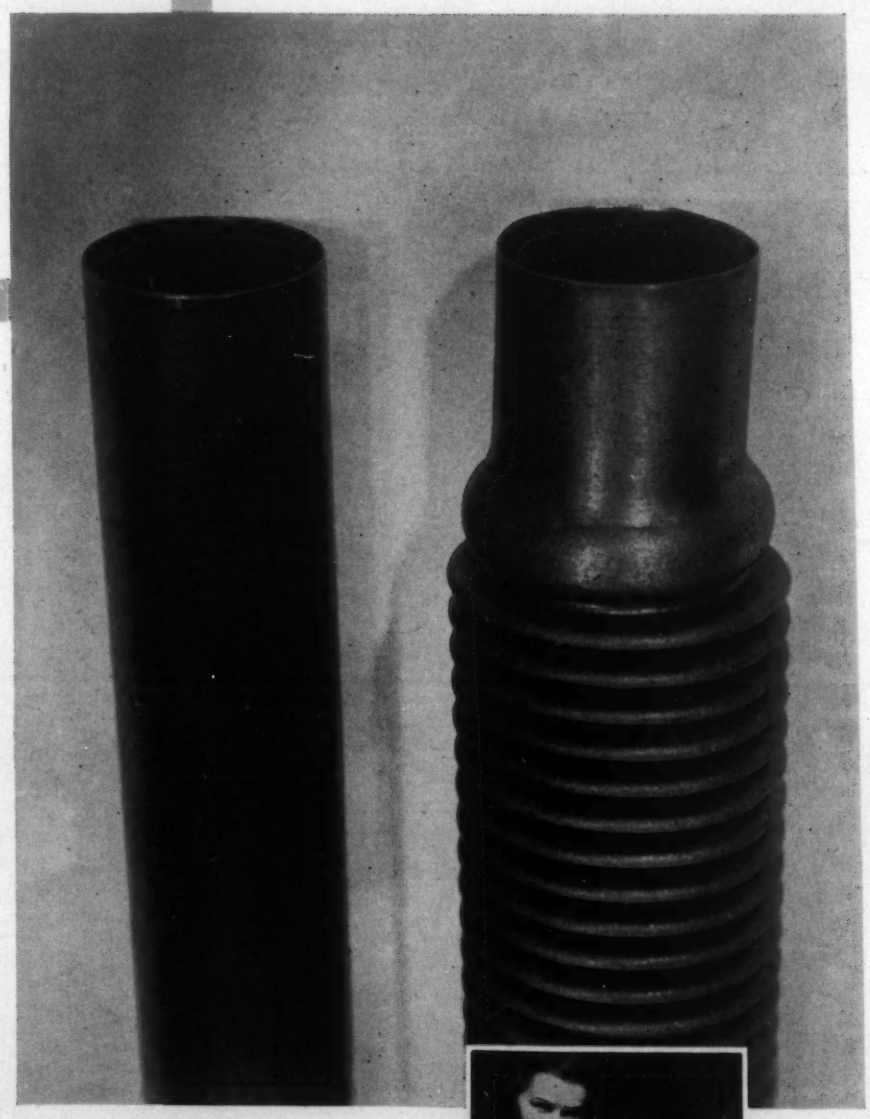

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METALLURGICAL ENGINEERING

shop notes

Tool Hardening Atmospheres

by Walter A. Schlegel
The Carpenter Steel Co.

Following the best of the usual instructions for hardening tool steel may often result in the loss of 0.70-0.30 per cent carbon from the surface of a 1.00 per cent carbon steel—simply because the general specifications to "use a reducing atmosphere" were followed.

The insidious feature of this is that the decarburization may be enough to make the part definitely inferior in quality, but not enough so that the softening is noticed in simple, quick or casual inspection. Even when the occurrence of decarb is recognized, and the "bark" ground off, there may still be many working surfaces (holes in blanking dies, for example) that are inaccessible to grinding, and whose cutting edges must remain soft and susceptible to burring and short die life.

Not all shops can justify the installation of elaborate and often expensive "bright hardening" atmosphere equipment. On the other hand, most simple partially-burnt fuel gas ("reducing") atmospheres, although they leave the surface bright, are usually decarburizing to plain carbon and low-alloy tool steels. Such decarburization can cause more spoilage and increase production costs far more than can a slight amount of scaling without decarburization. The best simple atmosphere that will do the latter is one that is *slightly* oxidizing to the steel in question at the temperature of treatment.

The amount of excess oxygen that should be present in such simple atmospheres will vary with the type of steel being treated, and can be controlled in any shop by certain interesting and surprisingly simple procedures, based on estimation "by eye" of the amount of excess oxygen in the atmosphere. Thus, a number of little blocks of wood (not over ¾-in. cube) is all that is needed for estimating oxygen up to 6 per cent, a few lumps of soft coal for 8-10 per cent oxygen, or a simple gas torch for 6-10 per cent oxygen.

For the wood-block test, have the furnace up to heat—say 1450 deg. F. Put a wood-block (any kind will do) on the hearth, close the door, and observe it through the peep-hole. Note these things, when first put in:

Does the block smoke?
Does it burn with a flame?
Is the flame intermittent or continuous?
Is the flame blue, partly luminous, or entirely so?

Temperature °F.	Oxygen Content %	Wood Block Behavior
1450 1550 1650	0-2.0 0-1.5 0-1.0	1. Wood block smokes and chars—no visible flame. The remaining charcoal does not glow
1450 1550 1650	2-2.5 1.5-2.0 1.0-1.5	2. Wood block smokes—then intermittent flashes of pale blue flame. The charcoal does not glow
1450 1550 1650	3.0-3.5 2.5-3.0 2.0-2.5	3. Wood block smokes slightly—then burns with an intermittent blue flame with luminous tip. Charcoal does not glow
1450 1550 1650	4.0-4.5 3.5-4.0 3.0-3.5	4. Trace of smoke. Wood block burns with steady lazy flame, mostly luminous. Flickering glow on edges of charcoal
1450 1550 1650	5.0-5.5 4.5-5.0 4.0-4.5	5. Wood block burns with a steady, active luminous flame. The charcoal definitely glows.

Above 5.5 per cent oxygen there is little change in the flame from a wood block.

Then, after several minutes, the wood will have become a piece of charcoal free from flame. Observe the charcoal:

It may not glow hotter than the furnace at all.
It may show a flickering glow on its corners and edges.
It may glow all over.

The test is now finished, and the oxygen content of the atmosphere can be obtained from the accompanying table. The test is accurate to within ± 1 per cent oxygen, which is close enough for all practical purposes.

Ten men—some of whom had never operated a hardening furnace in their lives—were given these instructions and asked to estimate various oxidizing atmospheres. After they had made their guesses "by eye," an actual chemical analysis was made. None missed the correct value by over 1 per cent, and many were within 0.5 per cent.

Of course, the heat treater has to know what per cent oxygen content is best for the particular steel being treated, and this he can do by a series of "standardizing" tests on his steels. Tests of this nature that we have run on Carpenter tool steels show that atmosphere No. 2 should be used for Solar (a water-hardening steel containing 0.50 per cent C, 1.0 Si, 0.5 Mo). For K-W (water-hardening, 1.30 per cent C, 3.5 W) atmosphere No. 3 was found best.

Atmosphere No. 3 was also the best for No. 11 Special (water-hardening, plain carbon, 1.10 per cent C); Stentor (oil-hardening, 0.9 per cent C, 1.60 Mn) and Excelo (0.55 per cent C, 2.5 W, 1.5 Cr, 0.35 V).

For oil-hardening steels like R.D.S. (0.75 per cent C, 1.75 Ni, 1.0 Cr) an atmosphere more oxidizing than any of the foregoing is desirable. Methods of estimating such high-oxygen contents, using soft coal or a gas torch, will be described in a later article.

Graphite crucibles are annealed in many foundries by placing them on top of a furnace—a practice that is advisable only provided considerable discretion is used. New crucibles usually contain 4-5 per cent moisture. If placed at once on top of a very hot furnace there is danger of an immediate "scalp"; even if there is no external damage, too sudden annealing might cause an internal fracture that would become a leak, or "pin hole," after a few heats.—American Crucible Co.

Testing Permanent Magnets

by M. C. Marsh

In testing the pole strength of permanent magnets, it is customary to use a search coil and fluxmeter or ballistic galvanometer. Accuracy and convenience can be considerably improved if *two* identical search coils are used differentially, with one drawn off a standard magnet at the same time the other is drawn off the sample under test.

If the standard has the minimum acceptable pole strength, a galvanometer deflection in one direction will indicate a good magnet, and in the opposite direction a poor one. Such testing is much easier and quicker for shop purposes than taking a scale reading in each case.

By using suitable pairs of search coils, the method can be applied to poles of unequal strength, permitting the use of a single standard pole in testing magnetic poles of any strength.

It is possible to devise a visual or audible alarm to signal the existence of a bad sample, or even to arrange for automatic sorting, if volume is sufficient. The impulse from the differential search coil may be amplified and applied to the grid of a thyratron or gas-filled relay, which operates the alarm or sorting mechanism. Or, alternatively, a high spot from the galvanometer can be deflected on to a photocell connected to the grid of the thyratron.—*Journal of Scientific Instruments.*

Bending Aluminum Aircraft Tubing

by Bert Freakley
Consolidated Aircraft Corp.

Manufacturing conditions in the aircraft industry make the tube bender's task much more difficult today than a few years ago, when a tube bent over a nail keg or one's knee might be satisfactory. Aluminum alloy tubes for oil and gas lines, for example, must be perfect in every respect, including the bends, before final inspection.

We have found that the use of a low-melting alloy as filler during bending not only results in perfect bends that are exactly reproducible at any future time, but also provides a means of checking for freedom from pinholes or other flaws in the material. The main purpose of the filler is simply to make the tube behave something like a solid bar and not flatten out at the point of bend, and for this non-metallic filler material (rosin or sand, for example) could be used. With sand or rosin, however, the filling process is tedious, inconvenient and sometimes unsafe, and the quality of the job is not always perfect.

Before bending, the tubes are visually inspected and cut to a length about 1-in. longer (for holding purposes) than that finally desired. Hardwood and rubber plugs, slightly tapered, are fitted snugly into one end of the tube and water at 160 deg. F. is poured in to bring the tube up to the same temperature as the molten filler alloy, which is next introduced. The filler in most common use is "Cerrobend" [50% Bi, 26.7 Pb, 13.3 Sn, 10 Cd, a designed-for-bending modification of Wood's metal produced by Cerro de Pasco Copper Corp., New York], which melts at 160 deg. F. The penetrative powers of the filler metal are such that some of it oozes through the close grain of the 1½-in. long plug.

At this stage, any pinholes, however small, will be revealed by the molten filler metal, which will come out through a hole finer than frog hair. If a defect has metal burnished in or over it, the Cerrobend will heave the metal out of the defect and expose the hole. If no defect was revealed, the filled tube is lowered slowly into cold water and left immersed while other tubes are being checked.

Now, suppose that *inside* this tube that has been left cooling there was a defect near the middle of the piece (the piece being 6-7 ft. long, 1 in. outside diam., of 0.049 in. 52 SO aluminum alloy) such that the wall thickness was actually only about 0.0005 in. The filler metal will raise a wart at that point as it solidifies during cooling, and will finally crack the tube open. A weak seam in the tubing will be split open in the same manner. This is because Cerrobend and similar alloys expand slightly on solidifying—enough to reveal any defects, but not to injure a sound tube.

Electrical conduit tubes, which do not have to be liquid tight, are bent with steel mandrels, no Cerrobend being used.

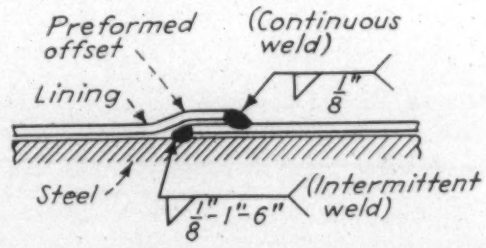
An Eastern foundry making castings weighing from a few ounces to several thousand lbs. had difficulty in finding a soft enough iron for a thin-sectioned small casting that had to be machined at high speed. A mixture with 2.90-3.00 per cent silicon, 0.20-0.25 phosphorus and 3.50-3.70 total carbon gave good results, but the machinability showed a decided improvement when the silicon was lowered to 2.40-2.50 and phosphorus raised to 0.40-0.50, with the total carbon remaining the same.— *Pig Iron Rough Notes,* Sloss-Sheffield Steel & Iron Co.

Lining Steel Tanks with Monel

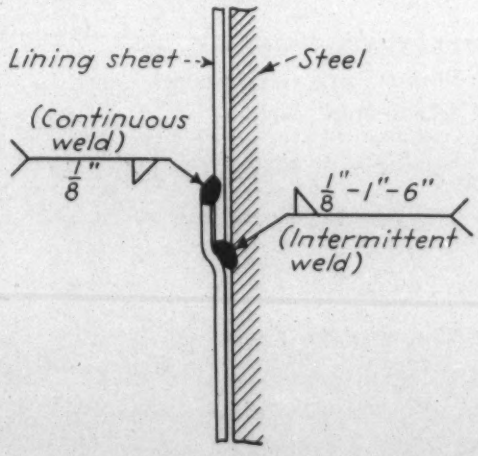
by Frank Flocke
The International Nickel Co., Inc.

Typical of the many large corrosion-resistant lining jobs that modern coated welding electrodes and improved techniques are making possible is the recently-accomplished lining of a steel Twitchell fat-splitting tank with 16-gage Monel by the Youngstown Welding and Engineering Co., Youngstown, Ohio.

The tank, measuring 12 ft. diam. by 18 ft. deep, was first cleaned. Monel sheets 36 in. by 96 in. No. 35 were pre-formed to provide an offset for lap welding, and were then rolled to the approximate diameter of the steel tank, the sheets being laid with their long dimension horizontal.



The upper course was applied first. Each sheet was permanently attached to the steel backing by intermittent welding. The adjacent Monel sheet was then lapped over this and tacked every 4 to 6 in. before making the final continuous arc weld. The upper diagram shows the detail of each horizontal lap joint, and the lower diagram, of the vertical lap joints.



Number 130-X Monel electrodes, of 3/32-in. diam., at a current of 65-70 amps., were used not only to complete the welding of the lining, but for the welds between the Monel sheet and the steel backing.

A shop specializing in difficult heat treating applications uses a novel method of heat control in the flame hardening of planer rails. Strips of cast iron are clamped on the sides of the rails, preventing the flames from heating the corners directly. The corners are thus kept soft while the remainder of the rail is properly hardened.—Oxy-Acetylene Tips, Linde Air Products Co.

Your editors want this new department (this is its second appearance) to become as nearly completely reader-written as possible, so urge anyone who has developed or is using some time-saving, trouble-saving or money-saving operating "kink" to submit it for publication. Payment will be made for all acceptable material that is original in nature—in other words, that has not appeared in print before. —The Editors.

Improved Quench Tank

by W. A. Lillienberg
Lindberg Steel Treating Co.

Quench tanks for production heat treatment, which must be provided with circulation and cooling, should be designed to ease the operator's job and at the same time eliminate overhead lifting tackle and permit quick draining and cleaning. The quench tank described herewith, designed by us, has been most satisfactory from these standpoints.

It consists of a cylindrical tank, 40 in. in diameter, provided with a perforated basket that is raised and lowered by a double-acting air cylinder under the tank. In addition, there is a perforated screen, which rests on the bottom of the tank and serves to retain scale, cyanide or other foreign matter that might otherwise get into the circulating system.

The basket is controlled by a 3-way air valve, can be raised or lowered quickly or slowly, and can be stopped at any level. Work that is too heavy to be agitated manually can be allowed to rest in the basket while it is alternately raised and lowered in the oil or water to produce maximum cooling effect. When the work has cooled sufficiently, the operator raises the basket above the level of the liquid and allows the work to drain before removal.

Where draining and cleaning of quench tanks used to be a dirty, disagreeable job requiring at least an hour, this tank can be drained, cleaned and put back in service in 10 min. To do this, the drain valve is opened and the basket is raised and removed by taking off the one nut that holds it to the air-cylinder shaft. The perforated screen in the bottom of the tank is then pulled up and the scale and other material on the screen is brushed off. The parts are then replaced just as quickly, and the tank put back in operation.

The screen in the bottom also catches any small pieces of work that fall between the basket and inside wall of the tank. Also, with this design no chain hoists and overhead tackle are required.

This air-operated quench tank can be built for about $200-$225, and pays for itself in a few months on the basis of convenience, and saving of time.

Drop forgings are used for the air-cooled cylinders in the Lycoming aircraft engine not only because of their characteristic "grain flow" but also because the metal on the inside of the forged cylinder is more compact than that on the outside—an aid to the attainment of the desired hardness within the cylinder barrel.— *Drop Forging Topics,* Drop Forging Assoc.

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